AN INTERACTIVE SOFTWARE PACKAGE FOR TIME SERIES ANALYSIS

Stephen Russell Woodall

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

AN INTERACTIVE SOFTWARE PACKAGE
FOR TIME SERIES ANALYSIS

by

Stephen Russell Woodall

September 1978

Thesis Co-Advisors: F.R. Richards
F.D. Faulkner

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Interactive Software Package for Time Series Analysis		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; September 1978
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Stephen Russell Woodall		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE September 1978
		13. NUMBER OF PAGES 242
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Time Series Analysis
FORTRAN
Time Series Editor
Box-Jenkins

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An expanded package of interactive FORTRAN computer programs has been developed for the analysis and forecasting of time series data. The package, called the Time Series Editor, is designed to employ the iterative Box-Jenkins methodology of time series analysis. The Time Series Editor was developed for time-shared use on the Control Program/Cambridge Monitor

(20. ABSTRACT Continued)

System (CP/CMS) at the U.S. Naval Postgraduate School, but can be modified for use on other time-sharing systems with a FORTRAN capability. The Time Series Editor assists in data preparation and entry, analysis, modeling, forecasting and diagnostic testing. Utilization of the package, following the included User's Guide, requires only a limited knowledge of the computer system, with all required user responses interactively prompted by the Editor.

20. ABSTRACT (Continued)

System (SPLICE) at the U.S. Naval Postgraduate School, and [illegible]

Approved for public release; distribution unlimited.

An Interactive Software Package for Time Series Analysis

by

Stephen Russell Woodall
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1967

Submitted in partial fulfillment of the requirements for the degrees of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

and

MASTER OF SCIENCE IN APPLIED MATHEMATICS

from the

NAVAL POSTGRADUATE SCHOOL
September 1978

ABSTRACT

An expanded package of interactive FORTRAN computer programs has been developed for the analysis and forecasting of time series data. The package, called the Time Series Editor, is designed to employ the iterative Box-Jenkins methodology of time series analysis. The Time Series Editor was developed for time-shared use on the Control Program/Cambridge Monitor System (CP/CMS) at the U.S. Naval Postgraduate School, but can be modified for use on other time-sharing systems with a FORTRAN capability. The Time Series Editor assists in data preparation and entry, analysis, modeling, forecasting and diagnostic testing. Utilization of the package, following the included User's Guide, requires only a limited knowledge of the computer system, with all required user responses interactively prompted by the Editor.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Operations researchers, military planners and programmers, statisticians, economists, marketing personnel, managers and others are often faced with the need to analyze data in the form of a time series, which can be thought of as a sequence of observations of either a deterministic or stochastic process. In most cases, the objective of the analysis is to determine patterns or other recognizable behavior apparent in the data, and to then formulate a suitable mathematical model for the time series from which forecasts of future behavior can be obtained. The value to a decision maker of being able to predict the future with some reasonable and statistically quantifiable degree of accuracy can not be overstated. For example, in areas such as budget expenditures, recruiting performance, commodity prices, population levels, resource consumption, manpower levels and consumer demand for products, decision makers charged with planning for the future should base their decisions at least in part on the best available predictions about the future behavior of the time series in question.

Until the late 1960's, the techniques employed in time series analysis were primarily those of spectral analysis, with applications of harmonic analysis and mathematical transform theory. For an introduction to these topics, the reader is referred to Anderson [Ref. 2], Lewis [Ref. 7] and Jenkins [Ref. 10]. Due to the high degree of mathematical

sophistication required by the spectral analysis approach, the capability to perform time series analysis resided nearly exclusively with mathematicians and electrical engineers. As a consequence, the majority of decision makers came to use more understandable (and far less powerful) methods such as simple moving averages or exponential smoothing. However, in the late 1960's and early 1970's, the statistical analysis of time series by the methods developed by Box and Jenkins [Ref. 4] has gained widespread acceptance. Although these methods are mathematically nearly equivalent to the spectral approach (there are transformations that interconnect the two methodologies), the Box-Jenkins approach is described in vocabulary more familiar to operations researchers, statisticians, economists and managers, and is therefore being used more and more by them in building models from measurements of the past.

Many algorithms and computer programs for performing the analyses required by the Box-Jenkins approach have been developed and are available from several sources. Perhaps the best source is the collection of FORTRAN computer subroutines which resides in the International Mathematical and Statistical Library (IMSL) [Ref. 9]. The primary problem with using the available computer resources lies not in any deficiency of the programs themselves, but with the very nature of the Box-Jenkins methodology itself. The Box-Jenkins method is an iterative approach to time series

analysis, which is briefly described in Figure 1. [See Wheelwright and Makridakis, Ref. 16.]

As indicated by Figure 1, the Box-Jenkins method is a multi-stage, iterative process. It begins with the postulation of a general class of time series models which has been found, experimentally, to be extremely rich. Thereafter, the procedure continues as a trial-and-error process, with decisions points where the analyst is required to select the next direction based on the best information available to him. Since each stage of the process outlined in Figure 1 may consist of several sub-steps, the modeling process itself can become quite time-consuming, even with the ready availability of the IMSL software resources. For example, an analyst employing the IMSL subroutines in a batch processing computer system to perform Box-Jenkins modeling of a time series might perform the following sequence of tasks:

1. Prepare the time series data in the proper format.
2. Plot and visually examine the time series, checking for nonstationarity, trends, seasonality, patterns, etc.
3. Write a program to call the IMSL subroutine that will calcuate the mean, variance, autocorrelations and partial autocorrelations of the series.
4. Plot the autocorrelations and partial autocorrelations; this provides much of the information required for identifying the correct model for the series.

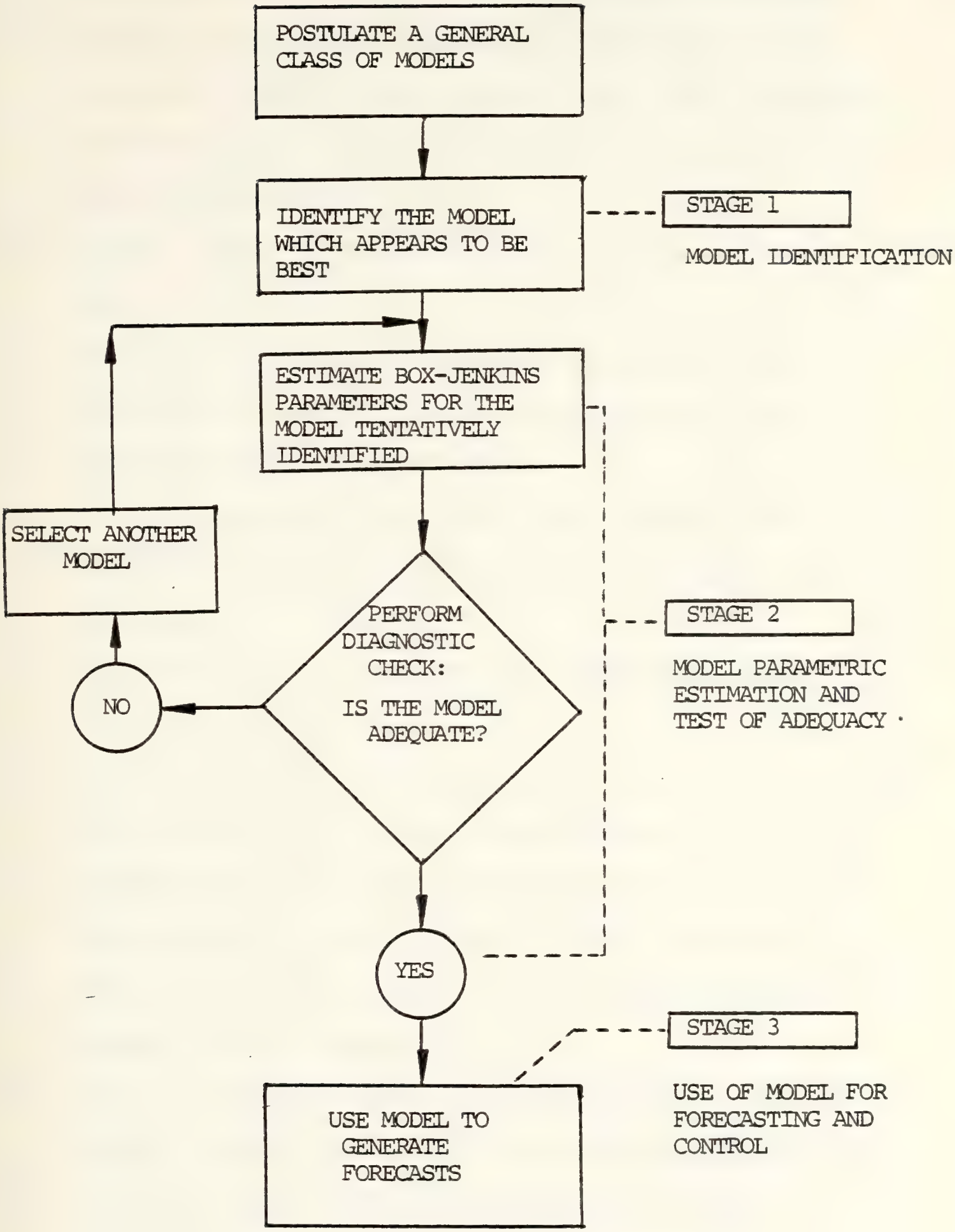


FIGURE 1. The Box-Jenkins Forecasting Methodology

5. Write a program to call the IMSL subroutine which transforms the time series to adjust for seasonal patterns, nonstationary behavior or other behavior which deviates from that assumed for the class of models postulated.
6. Repeat steps (2) through (4) with the transformed data.
7. Review the statistical properties of the auto-correlations and partial autocorrelations for tentative model identification.
8. Write a program to call the IMSL program that estimates the model parameters and computes the residuals.
9. Write a program to perform goodness-of-fit tests for the model.
10. Analyze the model residuals, using steps (1) through (9), as with the original time series.
11. Refine the model using information gained by examination for any structure in the residuals.
12. Repeat the preceding process until no structure remains in the residuals.
13. When an adequate model has been obtained, write a program to call the IMSL subroutine which forecasts and determines confidence intervals for future values of the time series.

Between each successive pair of steps, the analyst must manually intervene in the analysis process, making a decision

subjectively based on the information then available. Thus, much analyst interaction is necessary in order to determine a suitable mathematical model and forecast equation. Even with rapid computer job turnaround time, the process described above could easily consume a full working day or more.

This paper describes an effort to alleviate some of the organizational problems inherent in the modeling of time series using the Box-Jenkins iterative approach. This effort consists of an interactive computer program package which provides access in a structured way to the most useful IMSL and other subroutines necessary for Box-Jenkins time series analysis. This package, called the Time Series Editor, is written for use with the Naval Postgraduate School's Control Progam/Cambridge Monitor System (CP/CMS). Since all working programs with the exception of the executive routine itself are written in FORTRAN, the Time Series Editor should be adaptable for use on other FORTRAN-capable time-sharing systems. The Time Series Editor assists the analyst in data preparation and entry, model construction and diagnostic testing, and time series forecasting. In fact, with the User's Guide provided as an Appendix to this report, a complete Box-Jenkins time series analysis can be performed in a short time by even a novice computer user. For this reason, the Time Series Editor could be a valuable instructional tool for laboratory use in a time series course.

A brief overivew of Box-Jenkins methodology is provided in Chapter II, to serve as a point of reference for the material which follows. Chapter III contains a description of the algorithm employed to estimate non-linear least-squares parameters for a generalized (seasonal, nonseasonal, stationary, or nonstationary) Box-Jenkins model. Chapter IV contains descriptions of each of the major programs in the Time Series Editor. Chapters V and VI contain examples of actual use of the Time Series Editor, using a non-seasonal and a seasonal series, respectively. Chapter VII includes a summary of the report, and recommendations for future additions to the Time Series Editor. The Appendices include a User's Guide to the Time Series Editor, with instructions, sample user sessions and sample outputs, as well as listings of the Editor itself and all primary subprogram packages.

II. BOX-JENKINS METHODOLOGY: A PRIMER

This chapter provides a brief overview of the methodology developed for the analysis of time series data by G.E.P. Box and G.M. Jenkins, in order to facilitate understanding of the models and programs employed in the Time Series Editor. For more detail on the material covered in this chapter, the interested reader is referred to the texts by Anderson [Ref. 1], Box and Jenkins [Ref. 4], Pindyck and Rubinfeld [Ref. 15], Nelson [Ref. 14], and Mabert [Ref. 12].

A. LISTING OF NOTATION

The following is a listing of the notation employed in this chapter and in the remainder of this report. Each symbol is provided with a brief title or explanation of its use.

$\{z_t\}$	a time series
N	the length of the time series (number of terms)
$\bar{z}$, $\hat{\sigma}_z^2$	estimates of the mean and variance of the time series $\{z_t\}$
$\{z_t'\}$	transform of $\{z_t\}$, where $z_t' = (z_t + \zeta)^{\lambda}$ or $z_t' = \ln(z_t + \zeta)$
$\{W_t\}$	differenced series from $\{z_t\}$, where $W_t = \nabla^d \nabla_s^D z_t'$
ρ_k	autocorrelation of lag k
r_K	estimate of autocorrelation at lag k
∇^d	backward difference operator of order d

∇_s^D	seasonal backward difference operator of order D with season s
B^s	backward shift operator of order s
s	length of the time series' season
ϕ	non-seasonal autoregressive parameters (estimates, $\hat{\phi}$)
Φ	seasonal autoregressive parameters (estimates, $\hat{\Phi}$)
θ	non-seasonal moving average parameters (estimates, $\hat{\theta}$)
Θ	seasonal moving average parameters (estimates, $\hat{\Theta}$)
$\{a_t\}$	series of white noise terms of the process
σ_a^2	variance of the white noise process
$S(\hat{\phi},\hat{\theta})$	sum of squared residuals of the model
p	number of non-seasonal autoregressive parameters
P	number of seasonal autoregressive parameters
q	number of non-seasonal moving average parameters
Q	number of seasonal moving average parameters
$\psi(B)$	transfer function of a linear filter
ϕ_{kk}	partial autocorrelation of log k

B. TIME SERIES, STOCHASTIC MODELS AND STATIONARITY

A distinguishing feature of modern time series analysis is that the sequence of observations of a given variable is considered to be a realization of jointly distributed

random variables, such that the time series itself can be viewed as a stochastic process. A discrete stochastic time series, then, is a set of observations $(z_1, z_2, \ldots, z_t)$ generated sequentially in time by a set of jointly distributed random variables, where the actual data $(z_1, z_2, \ldots, z_t)$ represents a particular realization of some joint probability distribution function $f(z_1, z_2, \ldots, z_t)$. With this function determined in some way, a forecast z_{t+k} can be thought of as having been generated by a conditional probability distribution $f(z_{t+k} | z_1, z_2, \ldots, z_t)$. Now, the stochastic process which generates the time series $(z_1, z_2, \ldots, z_t)$ is said to be stationary if its properties are unaffected by a change in time origin; that is, the process has reached a particular state of statistical equilibrium. This implies that the joint probability distribution associated with the m observations $(z_{t_1}, z_{t_2}, \ldots, z_{t_m})$, made at any set of times $(t_1, t_2, \ldots, t_m)$, is identical to that distribution associated with the m observations $(z_{t_1+k}, z_{t_2+k}, \ldots, z_{t_m+k})$ made at times $(t_1+k, t_2+k, \ldots, t_m+k)$.

For stationary discrete time series, the marginal probability distribution $p(z_t)$ is the same for all times t. Hence, the stochastic process embodied in the time series has a constant mean

$$\mu = E[z_t] = \int_{-\infty}^{\infty} zP(z)dz ,$$

which defines the level about which it fluctuates in time, and a constant variance

$$\sigma_z^2 = E[(z_t - \mu)^2] = \int_{-\infty}^{\infty} (z -)^2 p(z)dz ,$$

which measures its variability about the level of the mean. Since the probability distribution p(z) is the same for all times t, its form can be discovered by plotting a histogram or relative frequency plot of the set of observations $(z_1, z_2, \ldots, z_t)$. Additionally, the mean and variance of the stochastic process can be estimated by the sample averages taken over time:

$$\bar{z} = \frac{1}{N} \sum_{t=1}^{N} z_t$$

and

$$\hat{\sigma}_z^2 = \frac{1}{N} \sum_{t=1}^{N} (z_t - \bar{z})^2 .$$

C. THE BASICS OF DIFFERENCE OPERATORS AND LINEAR FILTER MODELS

This section provides a brief discussion of the difference operators currently employed in writing Box-Jenkins models. Those most commonly used are described below in Table I.

Operator	Name	Definition
B^m	Backward Shift Operator of order m	$Bz_t = z_{t-1}$ $B^s z_t = z_{t-s}$
F^m	Forward Shift Operator of order m	$F = B^{-1}$ $Fz_t = z_{t+1}$ $F^m z_t = z_{t+m}$
∇_s^D	Backward Difference Operator of order D and season s	$\nabla^D = (1 - B)^D$ $\nabla_s^D = (1 - B^s)^D$ $\nabla z_t = z_t - z_{t-1}$

Table I. Basic difference operators.

It is noted here that $\nabla^D z_t$ could be written as a binomial expansion; that is,

$$\nabla^D z_t = (1 - B)^D z_t = \left(\sum_{j=0}^{D} \binom{D}{j} (1)^j (-B)^{D-j} \right) z_t$$

$$= \sum_{j=0}^{D} \binom{D}{j} (-1)^{D-j} z_{t-D+j} \, .$$

The stochastic models employed in the Box-Jenkins method are based on the idea that a time series in which successive

values are highly dependent can be regarded as having been generated from a series of independent "shocks" a_t. These shock terms, sometimes referred to as white noise terms, are random drawings from some fixed distribution, generally assumed Normal with mean zero and variance σ_a^2. The white noise process a_t is supposed transformed to the process z_t by what is known as a linear filter, shown in Figure 2 below [Ref. 4, p. 8]. The linear filtering operation takes a

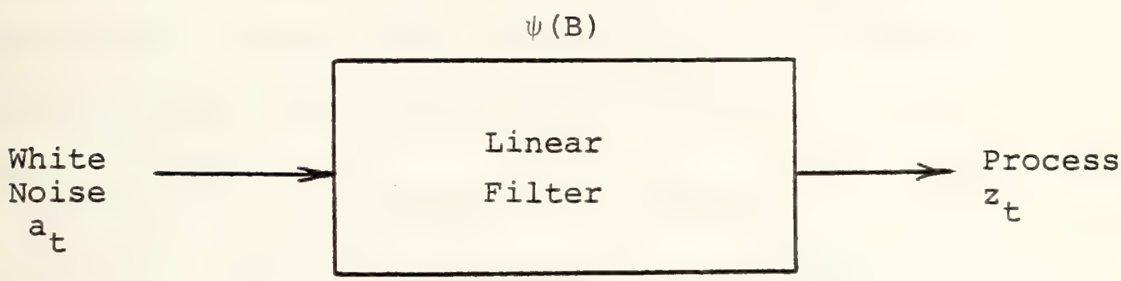


Figure 2. Representation of a time series as the output from a linear filter.

weighted sum of previous observations, such that z_t can be written

$$z_t = \mu + a_t + \psi_1 a_{t-1} + \psi_2 a_{t-2} + \cdots$$

$$= \mu + \psi(B) a_t .$$

In general, μ is the parameter that determines the "level" of the process, and

$$\psi(B) = 1 + \psi_1 B + \psi_2 B^2 + \ldots$$

is the linear operator that transforms a_t into z_t, called the transfer function of the filter. The sequence $\psi_1, \psi_2, \ldots$ formed by the weights may be (theoretically) finite or infinite; if this sequence is finite, or infinite and converges, the filter is said to be stable and the process z_t stationary. The parameter μ is then the value about which the process varies. Otherwise, z_t is called nonstationary, and μ has no specific meaning except as a reference point for the level of the process.

D. HOMOGENEOUS NON-STATIONARY AND SEASONAL PROCESSES

In many cases of interest to the time series analyst, the process being examined is not stationary. Instead, the probabilistic structure of the process generating the time series changes with time. For example, there may be a trend or seasonal pattern in the time series. However, if the series can be found to exhibit behavior which is somewhat homogeneous, then the series can frequently be transformed into a stationary series that can be described by Box-Jenkins models.

A series is said to be homogeneous nonstationary of order d if $w_t = \nabla^d z_t$ is a stationary series for some integer d. Here $\nabla = (1 - B)$ denotes the difference operator such that $\nabla^1 a_t = z_t - z_{t-1}$. The fact that a given series is nonstationary can be determined quickly by examination of

the autocorrelation function, to be discussed later. The series to be modeled should be differenced until the resulting series appears stationary or until the procedure appears to be making no improvement.

A time series is called seasonal when it exhibits cyclical behavior over time, showing a regular period. Examples of seasonal processes include monthly rainfall, monthly crop yields, sale volume of bathing suits, livestock production rates and energy consumption. Seasonal patterns are often easy to spot simply by observing a plot of the series, or through knowledge of the process that generated the series. However, in many cases where the variability of the series is large, seasonal patterns will be difficult to distinguish from other fluctuations. Recognition of seasonality in a series is important, since it provides information useful in modeling and forecasting; as will be shown, the autocorrelation function can assist in recognizing seasonality. The Box-Jenkins modeling approach for seasonal nonstationary time series of season length s is to first transform the series using an appropriate seasonal differencing operator to "sweep out" the seasonal effect; that is, take

$$w_t = \nabla_s^D z_t .$$

If there is a trend or other types of non-stationarity present, as well as the seasonal effect, the series can be

differenced again with the ordinary difference operator until stationarity is achieved. This transform would be written

$$W_t = \nabla^d \nabla_s^D z_t$$

The transformed series W_t is then modeled as a stationary series. For seasonal series where complete stationarity can not be achieved, a class of seasonal models is available; these are discussed later in this Chapter.

E. GENERAL CLASSES OF BOX-JENKINS MODELS

This section will provide brief descriptions of several of the most commonly used classes of Box-Jenkins models, including autoregressive (AR) models, moving average (MA) models, mixed and integrated autoregressive-moving average (ARMA/ARIMA) models, and a generalized seasonal ARIMA model.

1. Autoregressive Models

In autoregressive (AR) models, the current value of the series under study is expressed as a linear combination of previous series values that explain the current observation, plus an unexplained random (white noise) term a_t. For a stationary series, or one that has been transformed to stationarity, the deviation from the mean value for each period, $\tilde{z}_t = z_t - \mu$, can be modeled as dependent on weighted values of the previous deviations from the mean. The AR model can be written

$$\tilde{z}_t = \phi_1\tilde{z}_{t-1} + \phi_2\tilde{z}_{t-2} + \ldots + \phi_p\tilde{z}_{t-p} + a_t \; .$$

In the expressions which follow the tilde will be dropped, but it is to be understood that the mean has already been subtracted from each observation. This equation is called an autoregressive process of order p, where ϕ_j represents a scalar weighting coefficient for the j^{th} previous period. The model can also be written in more compact form as

$$\phi(B)z_t = a_t \; ,$$

where

$$\phi(B) = (1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p) \; ,$$

a polynomial in the operator B. Then, $\phi(B)$ represents a general non-seasonal AR operator. The reason these models are called autoregressive can be seen from recalling regression analysis; here the model relates the dependent variable z_t to a set of explanatory variables $(z_{t-1}, z_{t-2}, \ldots, z_{t-p})$, which are previous values of the time series. Therefore, the model is autoregressive. For example, when the value of the time series at time t depends only on the value at time t-1, the model becomes an autoregressive model of order 1, denoted AR(1). Similarly, if the value in period t depends on the values in periods t-1, t-2 and t-3,

the model is AR(3). The following equations are the mathematical representation of those two examples:

$$\text{AR(1)}: \quad z_t = \phi_1 z_{t-1} + a_t \ ;$$

$$\text{AR(3)}: \quad z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + \phi_3 z_{t-3} + a_t \ .$$

2. <u>Moving Average Models</u>

In moving average (MA) models, the assumption is made that the current value of the time series at period t can be expressed as a linear combination of the previous forecast errors (or, residuals), $a_t = z_t - \hat{z}_t$. The general equation for this model can be written

$$z_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} \ ,$$

which is called a moving average model of order q, where θ_q represents the scalar weighting coefficient for the q^{th} previous period. Like the AR model, the MA model can be written in more compact operator notation as follows:

$$z_t = \theta(B) a_t \ ,$$

where

$$\theta(B) = (1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q) \ ,$$

a polynomial in the operator B. The MA model implies that the analyst can gain valuable information for future predictions by consideration of the weighted sum of a number of previous forecast errors or residuals. The following are examples of MA models of order 1 and order 3, MA(1) and MA(3):

$$\mathrm{MA}(1): \quad z_t = (1 - \theta_1 B)a_t = a_t - \theta_1 a_{t-1};$$

$$\mathrm{MA}(3): \quad z_t = (1-\theta_1 B-\theta_2 B^2-\theta_3 B^3)a_t$$

$$= a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \theta_3 a_{t-3}.$$

3. Mixed and Integrated Autoregressive-Moving Average Models

A natural extension of the autoregressive and moving average models is to construct a combination of the two. Such mixed processes are called autoregressive-moving average (ARMA) processes, of orders p and q, often written as ARMA(p,q). Box and Jenkins [Ref. 4] notes that for many series encountered in practice, the inclusion of both AR and MA terms in a model results in fewer total parameters than would be required for either a pure AR or pure MA process. The ARMA(p,q) model may be written in the usual form as

$$z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + \cdots + \phi_p z_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \cdots - \theta_q a_{t-q};$$

in the more compact operator notation, the same model is written

$$\phi(B)z_t = \theta(B)a_t .$$

As an example, an ARMA(2,2) model would be written as:

$$(1-\phi_1 B-\phi_2 B^2)z_t = (1-\theta_1 B-\theta_2 B^2)a_t ,$$

or expanded, as:

$$z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} .$$

Recall that with differencing or other transformation techniques, a stationary series can be obtained from a homogeneous (seasonal or non-seasonal) non-stationary series. When the differencing technique is integrated directly into the ARMA model, the result is an integrated autoregressive-moving average (ARIMA) model. The model is often written ARIMA(p,d,q), where p and q retain their previous meanings, and d represents the order of (non-seasonal) differencing. The model may also be generalized by including an additional constant term θ_o that will have the effect of adding a deterministic polynomial trend of order d. The value of θ_o may be found in general by the formula

$$\hat{\theta}_o = \hat{\mu} G ,$$

where

$$G = [1 - \sum_{i=1}^{p} \hat{\phi}_i][1 - \sum_{j=1}^{P} \hat{\Phi}_j] .$$

The general ARIMA(p,d,q) model can be written compactly as

(1) $$\phi(B) \nabla^d z_t = \theta_o + \theta(B) a_t .$$

An equivalent form for ARIMA(p,d,q) models that is sometimes seen is called undifferenced form:

$$\Psi(B) z_t = \theta_o + \theta(B) a_t ,$$

where

$$\Psi(B) = \phi(B) \nabla^d = \phi(B)(1 - B)^d .$$

The "differenced" form, equation (1), is the form usually seen. In the differenced form, the transfer function $\phi(B)$ is assumed to be stable; that is, all the roots of the difference equation $\phi(B) = 0$ are outside the unit circle. Clearly, $\Psi(B)$ is not a transfer function of a stationary series when $d > 0$, since $\Psi(B)$ has d roots on the unit circle.

4. Seasonal ARIMA Models

The general class of ARIMA models previously discussed can be further generalized to allow for the modeling of seasonal models with the addition of appropriate seasonal operators and parameters. The seasonal model is called an ARIMA model of order $(p,d,q) \times (P,D,Q)_s$, where p,d, and q retain their previous meanings, and P, D, Q and s are as defined in Section A of this chapter, page 17. The ARIMA $(p,d,q) \times (P,D,Q)_s$ model can be written as the product of nonseasonal and seasonal operators:

$$\phi(B)\Phi(B^s)\nabla_s^D\nabla^d z_t = \theta_o + \theta(B)\Theta(B^s)a_t .$$

As an example, consider the ARIMA $(1,2,1) \times (1,2,1)_{12}$ model:

$$(1-\phi_1 B)(1-\Phi_{1,12}B^{12})\nabla^2\nabla_{12}^2 z_t = \theta_o + (1-\theta_1 B)(1-\Theta_{1,12}B^{12})a_t .$$

F. THE AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS

Mathematically, the autocorrelation at lag k, denoted ρ_k, is defined as:

$$\rho_k = \frac{E[(z_t - \mu)(z_{t+k} - \mu)]}{\sigma_z^2} .$$

The autocorrelation function of a time series describes the association (mutual dependence) among values of the same

series taken at different time periods, the difference in time being referred to as the lag, denoted k. Autocorrelation of itself implies nothing about a change in one variable causing a change in another. However, the autocorrelations may provide important information about the structure of a data set and its pattern. In a set of completely random data the theoretical autocorrelations among successive values will always be zero, whereas data values of strong seasonal or cyclical behavior will be highly autocorrelated. This ρ_k can be estimated using the time-averaged sample autocorrelation, denoted r_k, defined as:

$$r_k = \frac{\frac{1}{N}\sum_{t=1}^{N-k}(z_t - \bar{z})(z_{t+k} - \bar{z})}{\hat{\sigma}_z^2}$$

A plot of the autocorrelation function versus the lag k, called a correlogram, is very useful for the purpose of determining if a process is stationary and for identifying the appropriate model.

Another function useful in identifying the appropriate model for a given series is the partial autocorrelation function, often called the pauto function. Partial autocorrelations are analogous to autocorrelations in that they indicate the relationship of the values of a time series to various time-lagged values of the same series. However, they differ from autocorrelations in that they measure the

strength of the relationship between values of the series of various lags after the effects of other lags have been removed. In effect, they show the relative strength of the relationship that exists for varying time lags. For time series models of the types to be considered, the partial autocorrelation coefficients can be calculated several ways. One method of calculation, described by Box and Jenkins [Ref. 4, Sec. 3.2.5] begins with the following equation, satisfied by the autocorrelation function, where the ϕ_k are autoregressive parameters:

$$\rho_j = \phi_{k1}\rho_{j-1} + \cdots + \phi_{k,k-1}\rho_{j-k+1} + \phi_{kk}\rho_{j-k}, \quad j = 1,2,\ldots, k$$

This leads to what are known as the Yule-Walker equations, which may be written

$$\begin{bmatrix} 1 & \rho_1 & \rho_2 & \cdots & \rho_{k-1} \\ \rho_1 & 1 & \rho_1 & \cdots & \rho_{k-2} \\ \vdots & \vdots & \vdots & & \vdots \\ \rho_{k-1} & \rho_{k-2} & \rho_{k-3} & \cdots & 1 \end{bmatrix} \begin{bmatrix} \phi_{k1} \\ \phi_{k2} \\ \vdots \\ \phi_{kk} \end{bmatrix} = \begin{bmatrix} \rho_1 \\ \rho_2 \\ \vdots \\ \rho_k \end{bmatrix}$$

Solving these equations for k = 1,2,3, ..., successively, we obtain

$$\phi_{11} = \rho_1 ,$$

$$\phi_{22} = \frac{\begin{vmatrix} 1 & \rho_1 \\ \rho_1 & \rho_2 \end{vmatrix}}{\begin{vmatrix} 1 & \rho_1 \\ \rho_1 & 1 \end{vmatrix}} = \frac{\rho_2 - \rho_1^2}{1 - \rho_1^2} ,$$

$$\phi_{32} = \frac{\begin{vmatrix} 1 & \rho_1 & \rho_1 \\ \rho_1 & 1 & \rho_2 \\ \rho_2 & \rho_1 & \rho_3 \end{vmatrix}}{\begin{vmatrix} 1 & \rho_1 & \rho_2 \\ \rho_1 & 1 & \rho_1 \\ \rho_2 & \rho_1 & 1 \end{vmatrix}} , \text{ etc.}$$

In general, for ϕ_{kk}, the determinant in the numerator has the same elements as that in the denominator, but with the last column replaced with ρ_k. The quantity ϕ_{kk}, a function of the lag k, is called the partial autocorrelation function. Other methods for calculating partial autocorrelations include successively fitting autoregressive processes of orders 1, 2, ..., k by least squares and picking off estimates of $\hat{\phi}_{11}$, $\hat{\phi}_{22}$, ..., $\hat{\phi}_{kk}$ of the last coefficient fitted at each stage. Another method, discussed in Appendix A3.2 of Ref. 4 and due to Durbin, generates estimates of an autoregressive process of order k+1 recursively from estimates of autoregressive processed orders k and less. It is derived by observing recursive relationships from the Yule-Walker equations. The recursive formulas are:

$$\hat{\phi}_{k+1,j} = \hat{\phi}_{k_j} - \hat{\phi}_{k+1,k+1}\hat{\phi}_{k,k-j+1} ,$$

$j = 1,2, \ldots, k$, and

$$\hat{\phi}_{k+1,k+1} = \frac{r_{k+1} - \sum_{j=1}^{k} \hat{\phi}_{kj} r_{k+1-j}}{1 - \sum_{j=1}^{k} \hat{\phi}_{kj} r_j} .$$

Another way of looking at partial autocorrelations is to consider a time series $\{z_t\}$ and the model

$$\hat{z}_t = b_o + b_1 z_{t-1} + b_2 z_{t-2} + \cdots + b_{k-1} z_{t-(k-1)} ,$$

where the b values are the least squares estimates of the linear regression coefficients (β's) in the model

$$z_t = \beta_o + \beta_1 z_{t-1} + \cdots + \beta_{k-1} z_{t-(k-1)} + e_t .$$

Let $\tilde{z}_t$ be the residual of z_t after removing the linear effect of $z_{t-1}, \ldots, z_{t-k+1}$ from z_t, such that $\tilde{z}_t = z_t - \hat{z}_t$. Then, the partial autocorrelation of lag k, denoted ϕ_{kk}, is defined to be the simple autocorrelation of lag k for the adjusted series $(\tilde{z}_1, \tilde{z}_2, \ldots, \tilde{z}_n)$.

The exact expression for partial autocorrelations of a moving average process is complicated, but an approximate duality between autocorrelations of an autoregressive

process and pautos of a moving average process implies that the pautos of a moving average process would have the same general behavior as the autocorrelations of an autoregressive process of the same order. This approximate duality also implies that the pautos of an autoregressive process of order p will have the same general behavior as the autocorrelations of a moving average process of order p. Thus, one function can be examined and used to confirm the other, and may be of use in model identification, discussed in section G of this chapter.

G. COMMENTS ON MODEL SELECTION EMPLOYING AUTOCORRELATIONS AND PARTIAL AUTOCORRELATIONS

The purpose of this section is to provide a brief overview of the methodology for selecting the proper model for a given time series, through both examination or prior knowledge of the data itself and examination of plots of the autocorrelation and partial autocorrelation functions.

A not yet stationary series should first be differenced or transformed until it appears to be stationary; characteristic of the autocorrelation plot (correlogram) of a nonstationary series is a very slow damping out of the autocorrelations. When this property of the correlogram is observed, the analyst should difference the series until no further improvement is reached. For ARMA(p,q) models, the tentative identification of the model class, that is, the determination of p and q, can be done by examining the

sample autocorrelation and sample partial autocorrelation functions of the given time series with the theoretical auto and pauto functions of members of the general linear class. For most stationary time series, an adequate fit can be found in a model with p and q relatively small, say three or less.

The following figure displays examples of autocorrelation and partial autocorrelation versus lag plots for several basic model types, described in Ref. 17.

Figure 3. Examples of Auto and Pauto Plots

Figure 3(a). Auto and Pauto vs. Lag for AR(1) Model

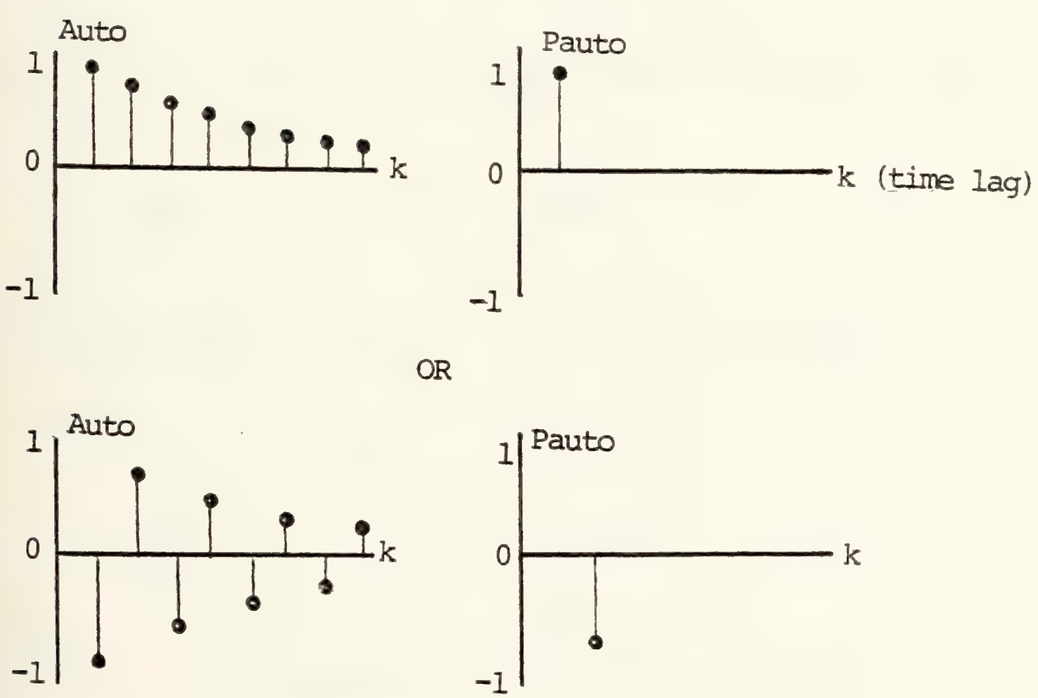


Figure 3(b). Auto and Pauto vs. Lag for AR(2) Model

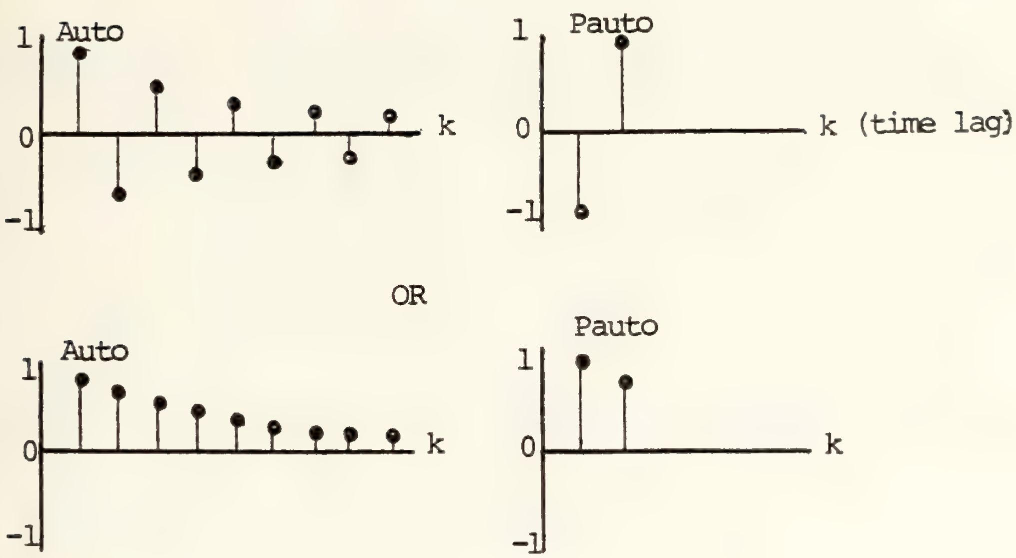


Figure 3(c). Auto and Pauto vs. Lag for MA(1) Model

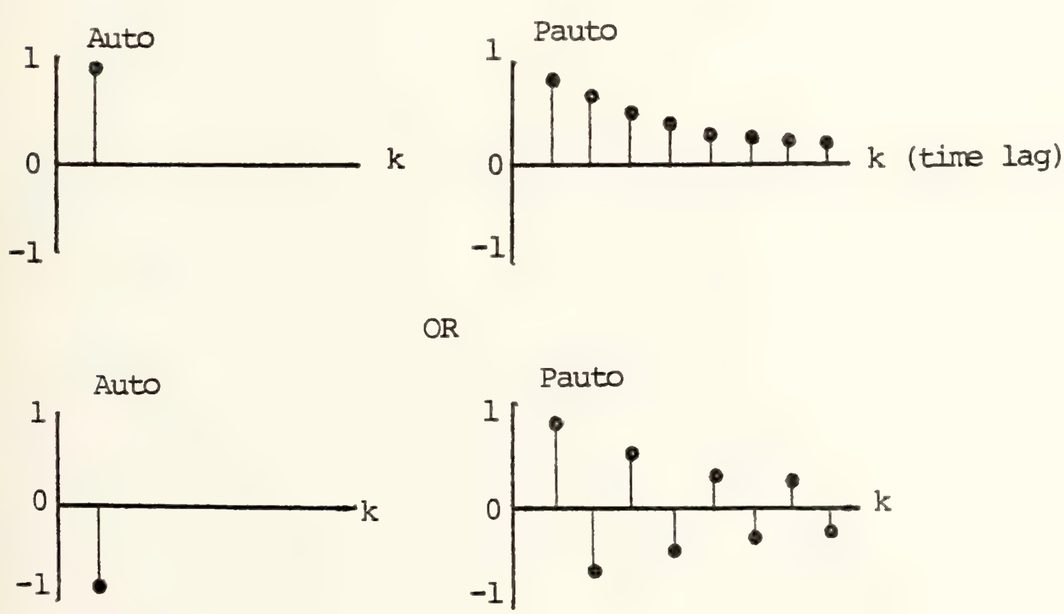


Figure 3(d). Auto and Pauto vs. Lag for MA(2) Model

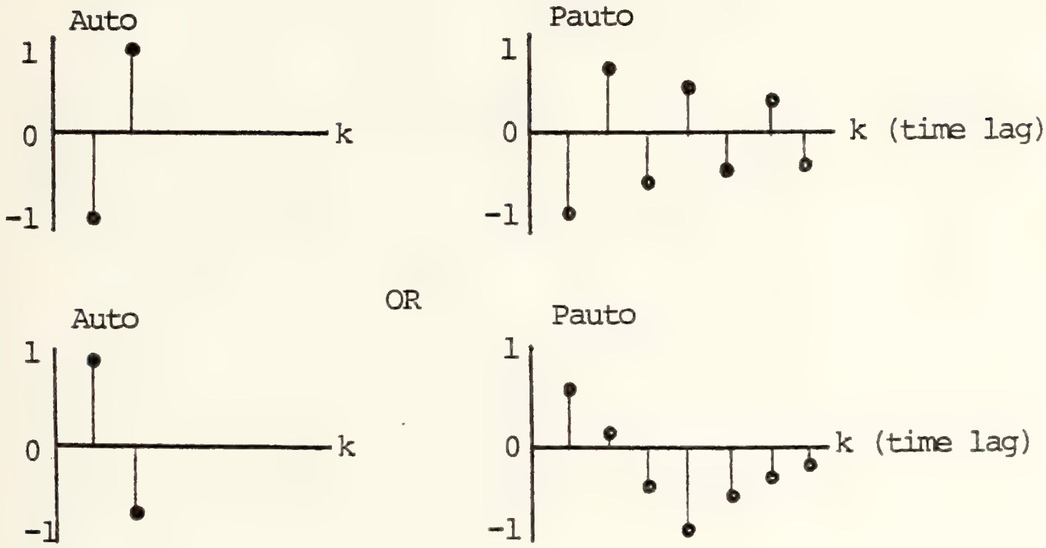
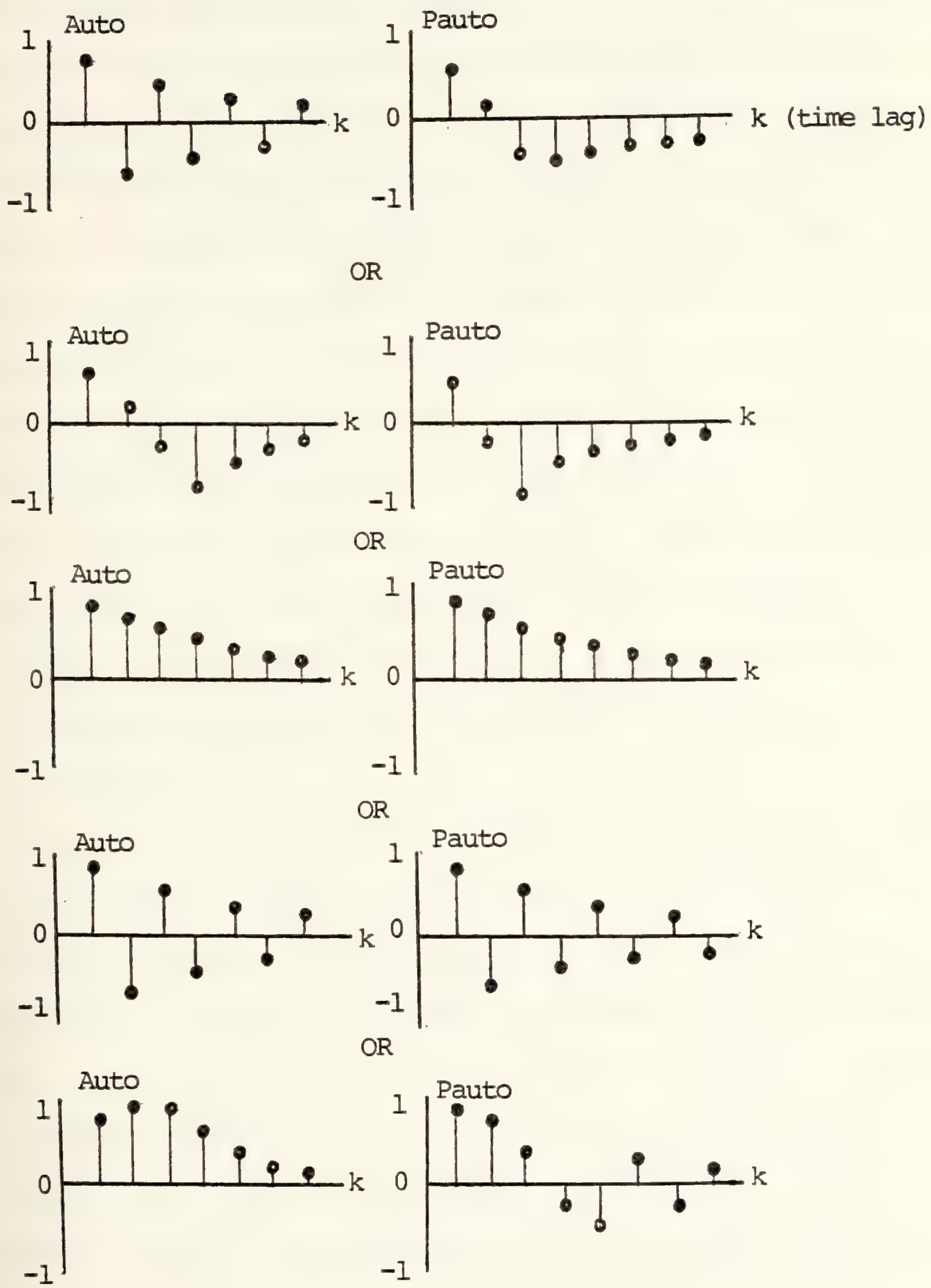


Figure 3(e). Example Auto and Pauto vs. Lag for Mixed ARMA(1,1) Model



As can be seen from the figures, there is a wide variety of possibilities for appearance of the correlogram and partial autocorrelation plots for even the simplest of models. Sometimes the pattern of estimated autos and pautos can be quickly classified in terms of one of the simpler basic models; however, most real data will generate auto and pauto plots that resemble those of Figure 3(e), those of a mixed model. Here some free association may be required to infer a pattern from the correlogram, or more than one pattern may be implied. However, most of the time a selection of something is possible. As is evident, this is a somewhat subjective process, where the quality of identification will improve with experience.

The following table, adapted from Box and Jenkins [Ref. 4], summarizes the properties of autoregressive, moving average and mixed ARMA processes; an understanding of its contents will be helpful as thumbrules for initial model identification.

It can be noted from examination of Table II that there exists what can be termed a "duality" relationship between the autocorrelations and partial autocorrelations of pure autoregressive and moving average processes. For example, the plot of autocorrelation versus lag for an AR(p) process would appear the same as the plot of partial autocorrelation versus lag for an MA(q) process, for p = q. Similarly, the plot of partial autocorrelation versus lag for the AR(p)

	Autoregressive Process	Moving Average Process	Mixed Process
Model in terms of previous z_t values	$\phi(B)\tilde{z}_t = a_t$	$\tilde{z}_t = \theta(B)a_t$	$\phi(B)\tilde{z}_t = \theta(B)z_t$
Autocorrelation Function	Infinite and tails off; composed of damped exponentials and/or damped sine waves	finite; that is, there will be q non-zero autocorrelations	Infinite and tails off; composed of damped exponentials and/or damped sine waves after the first q-p lags
Partial Autocorrelation Function	finite; that is, there will be p non-zero partial autocorrelations	Infinite and tails off; dominated by damped exponentials and/or sine waves	Infinite and tails off; composed of damped exponentials and/or sine waves after the first p-q lags

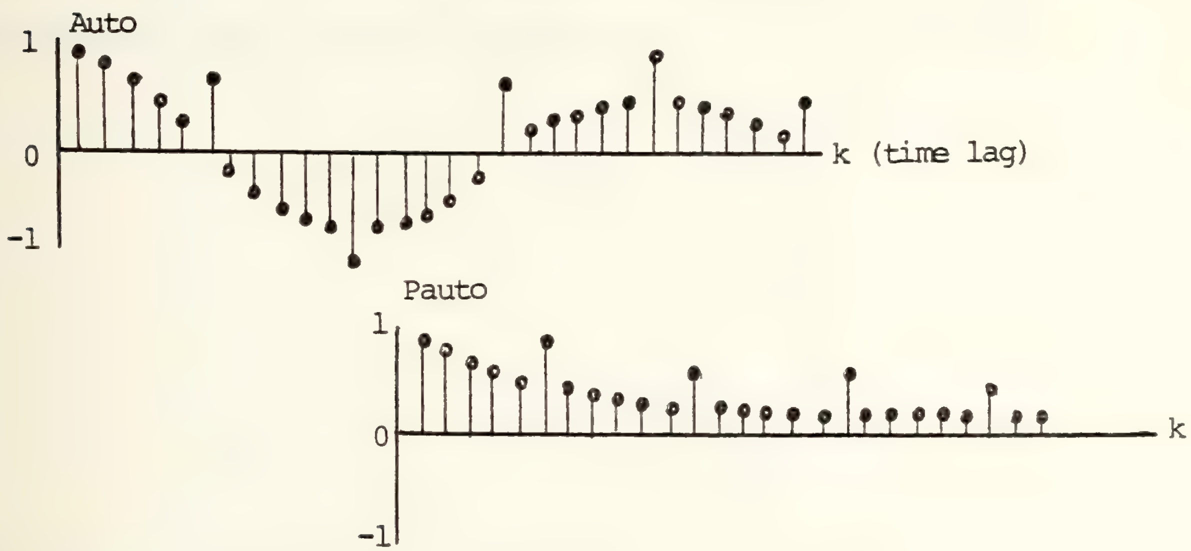
Table II. Properties of Basic ARMA Processes

process would appear the same as the plot of autocorrelation versus lag for an MA(q) process, where p = q.

For seasonal series, where differencing has been unable to remove all the nonstationary seasonal behavior, the autocorrelation and partial autocorrelation plots will generally exhibit a "spike" at lags equal to integer multiples of the period of seasonality. For example, if the data are seasonal with a period of 12, then the autocorrelations

$r_{12}, r_{24}, r_{36}, \ldots$ and the partial autocorrelations $\phi_{12,12}, \phi_{24,24}, \phi_{36,36}, \ldots$ would be amplified. This would indicate a need for one or more seasonal parameters to be included in the model. The following figure is an illustration of such an auto/pauto plot.

Figure 4. Example Auto and Pauto versus lag for mixed ARMA(p,q), with seasonality remaining of period s = 6.



H. ESTIMATION OF MODEL PARAMETERS

Suppose a time series has been tentatively identified as an ARIMA(p,d,q) model:

$$\phi(B)\ \nabla^d\ z_t = \theta_o + \theta(B)\ a_t .$$

There are then p+q+2 unknown parameters of the model to be estimated, $(\phi_1, \phi_2, \ldots, \phi_p, \theta_o, \theta_1, \theta_2, \ldots, \theta_q, \sigma_a^2)$. The

Box-Jenkins procedure separates this estimation into two parts. First, estimates are obtained for the AR and MA parameters $\hat{\phi} = (\phi_1, \phi_2, \ldots, \phi_p)$ and $\hat{\theta} = (\theta_1, \theta_2, \ldots, \theta_q)$; then estimates are calculated for θ_o and σ_a^2, which are functions of $\hat{\phi}$ and $\hat{\theta}$.

The usual procedure is to select those parameter values $\hat{\phi}$ and $\hat{\theta}$ that minimize the sum of squared model errors (residuals). Let $\mu_w = \theta_o/(1 - \phi_1 - \phi_2 - \cdots - \phi_p)$ and $\tilde{W}_t = \nabla^d(z_t - \mu_w)$. Then, it can be shown that $\mu_w = E[W_t]$ and that the model can be rewritten as

$$\phi(B)\ (W_t - \mu_w) = \theta(B)\ a_t\ ,$$

or

$$a_t = \theta^{-1}(B)\ \phi(B)\ (W_t - \mu_w)\ .$$

Now, let $\bar{W}$, the sample mean, be the estimate of μ_w (if $d > 0$, then μ_w is usually zero). Also, let

$$a_t = \hat{\theta}^{-1}(B)\ \hat{\phi}(B)\ (W_t - \bar{W}).$$

Set

$$S(\hat{\underline{\phi}}, \hat{\underline{\theta}}) = \sum_{t=1}^{N} a_t^2\ ,$$

where $N = n\text{-}d$ is the length of the differenced series. The

objective is to select those parameters $\hat{\underline{\phi}}$ and $\hat{\underline{\theta}}$ such that $S(\hat{\underline{\phi}},\hat{\underline{\theta}})$ is minimized over all values of the (p+q)-dimensioned parameter space. Since the equation in S is nonlinear in the parameters, iterative search methods are generally used to determine optimal model parameters. Having found these optimal parameters and the minimum S, σ_a^2 can be estimated using

$$\hat{\sigma}_a^2 = S(\hat{\underline{\phi}},\hat{\underline{\theta}})/N-p-q \ .$$

Chapter III contains a more detailed description of a nonlinear algorithm to estimate parameters of a generalized seasonal or nonseasonal ARIMA model.

I. DIAGNOSTIC CHECKING OF MODELS

After the model has been tentatively identified and parameter estimates have been calculated, the next task is to test whether or not the original model specification was correct and that the model itself is adequate in forecasting power. The process of testing the model can take many forms, but will usually include at least the following two steps:

1. Generate a simulated series from the estimated model and compare the simulated series and its auto and pauto functions with the original series and its respective auto and pauto functions. This comparison is essentially subjective.

2. Calculate the residuals of the estimated model, the $\hat{a}_t$'s, and compare the properties of the residuals with those assumed for the shock terms of the actual process. The residuals should be normally distributed and uncorrelated with each other; that is, there should be no discernable structure in the residuals. There are many quantitative statistical tests and data analytic tools that can be applied to the residuals to test hypotheses of normality and zero autocorrelation.

A plot of the autocorrelation and partial autocorrelation functions of the residuals will provide not only a test of whether or not the residuals are uncorrelated, but, if they are correlated, the plots can be used to suggest improvements to the model. For example, suppose the model was tentatively specified as the ARMA(1,1) model below:

$$(1 - 0.5B)(z_t - 2) = (1 + 0.7B)\, a_t .$$

Suppose also that the autos and pautos of the model residuals suggested the model $(1 - 0.3B)\, a_t = u_t$, where the u_t's are white noise, uncorrelated with variance σ_u^2. Then, these two models can be combined into the ARMA(2,1) model:

$$(1 - 0.3B)\,(1 - 0.5B)\,(z_t - 2) = (1 + 0.7B)\, u_t .$$

This should be a refinement over the original model.

J. FORECASTING

The objective in forecasting is to predict future values of the time series with as little error as possible. The criterion most often used for forecasting is to calculate that forecast which minimizes the expected mean square forecast error. Therefore, if $\hat{z}_t(\ell)$ denotes the forecast for lead time ℓ from time origin t of the value $z_{t+\ell}$, the objective is to find $\hat{z}_t(\ell)$ such that the objective function

$$E[(z_{t+\ell} - \hat{z}_t(\ell)^2]$$

is a minimum. This forecast is given by taking $\hat{z}_t(\ell)$ as the conditional expectation of $z_{t+\ell}$, given $z_1, \ldots, z_t$:

$$\hat{z}_t(\ell) = E[z_{t+\ell}|z_t, z_{t-1}, \ldots, z_1] .$$

The forecast can be easily generated recursively from the mathematical model, utilizing the facts that

$$E[z_{t-j}|z_t, \ldots, z_1] = z_{t-j} ,$$

for j = 0,1,2... (where t is the current time), and

$$E[z_{t+j}|z_t, \ldots, z_1] = \hat{z}_t(j), \text{ for } j = 1,2, \ldots$$

and

$$E[a_t] = \begin{cases} 0 & \text{for times} > t \\ a_t & \text{for times} \leq t \end{cases}$$

For example, consider the Box-Jenkins model

$$(1 - 0.5B + 0.6B^2)\ z_t = (1 + 0.3B)\ a_t$$

which could be written in the expanded form as

$$z_t = 0.5z_{t-1} - 0.6z_{t-2} + a_t + 0.3\ a_{t-1} .$$

Now, assume it is known that z_{100} is 1.4, z_{99} is 1.0, and the calculation has been made to obtain the residual $\hat{a}_{100} = 0.2$. Then the forecasts of z_{101}, z_{102} and z_{103} made from an origin of $t = 100$ can be calculated from the model as follows:

first, for $\ell = 1$, set

$$\hat{z}_{100}(1) = E[z_{101} | z_{100}, z_{99}, \ldots, z_1] ,$$

$$\hat{z}_{100}(1) = E[0.5z_{100} - 0.6z_{99} + \hat{a}_{101} + 0.3\hat{a}_{100}] ,$$

and

$$\hat{z}_{100}(1) = (0.5)(1.4) - (0.6)(1.0) + 0 + (0.3)(0.2) \;;$$

then our forecast

$$\hat{z}_{100}(1) = 0.7 - 0.6 + 0.06 = 0.16 \;;$$

Next, for $\ell = 2$, set

$$\hat{z}_{100}(2) = E[z_{102}|\hat{z}_{101}, z_{100}, z_{99}, \ldots, z_1] \;,$$

$$\hat{z}_{100}(2) = E[0.5\hat{z}_{101} - 0.6z_{100} + a_{102} + 0.3a_{101}$$

$$|z_{100}, z_{99}, \ldots, z_1] \;,$$

$$\hat{z}_{100}(2) = (0.5)(\hat{z}_{100}(1)) - (0.6)(z_{100}) + 0 + 0 \;,$$

$$\hat{z}_{100}(2) = (0.5)(0.16) - (0.6)(1.4) = -0.76 \;;$$

similarly, for $\ell = 3$, set

$$\hat{z}_{100}(3) = E[z_{103}|\hat{z}_{102}, \hat{z}_{101}, z_{100}, z_{99}, \ldots, z_1] \;,$$

$$\hat{z}_{100}(3) = E[0.5\hat{z}_{102} - 0.6\hat{z}_{101} + a_{103} + 0.3a_{102}$$

$$|z_{100}, z_{99}, \ldots, z_1]$$

$$\hat{z}_{100}(3) = (0.5)(\hat{z}_{100}(2)) - (0.6)(\hat{z}_{100}(1)) + 0 + 0 \;,$$

and then

$$\hat{z}_{100}(3) = (0.5)(-0.76) - (0.6)(0.16) = -0.48 .$$

Clearly, this process can be continued into the future as long as desired, recognizing that the expected forecast accuracy will decrease as ℓ increases.

Let

$$e_t(\ell) = (z_{t+\ell} - \hat{z}_t(\ell))$$

denote the forecast error for lead time ℓ beyond the forecast time origin t. It can be shown that $e_t(\ell)$ is given by the relation

$$e_t(\ell) = a_{t+\ell} + \psi_1 a_{t+\ell-1} + \ldots + \psi_{\ell-1} a_{t+1} ,$$

where the scalar weights ψ_j are determined from the equation

$$\psi(B) = \hat{\phi}^{-1}(B)\ (1 - B)^{-d}\ \hat{\theta}(B)$$

using the known parameter values. The variance of the forecast error is given by

$$E[(e_t^2(\ell)] = (1 + \psi_1^2 + \ldots + \psi_{\ell-1}^2)(\sigma_a^2) = \{1 + \sum_{j=1}^{\ell-1} \psi_j^2\}\sigma_a^2 .$$

From these relationships, a confidence interval of n standard deviations about a forecast of lead time ℓ would be given by:

$$c_n(\hat{z}_t(\ell)) = \hat{z}_t(\ell) \pm n[1 + \sum_{j=1}^{\ell-1} \psi_j^2]^{1/2} \hat{\sigma}_a .$$

The value of n could also be though of as the percentage point for the desired level of confidence using the Normal distribution [Ref. 4]. It can be noted from the definition of $e_t(\ell)$ above that the one-step-ahead forecast error, $e_t(1)$ is simply the value a_{t+1}; that is,

$$z_{t+1} - \hat{z}_t(1) = e_t(1) = a_{t+1} .$$

This is an explanation for the use of the term "residual" to refer to the white noise or shock terms. Additionally, from the foregoing it is evident that the forecast error variance is a non-decreasing function of the length of the forecast lead time ℓ; therefore, the confidence bands must become wider as the forecast lead time increases.

III. GENERALIZED ARIMA MODEL PARAMETER ESTIMATION

The purpose of this chapter is to describe the computational details of the algorithm WMARQRDT, employed with appropriate subroutines to estimate Box-Jenkins parameters of a generalized seasonal (or non-seasonal) ARIMA model. This generalized model can be written parsimoniously as follows:

$$\phi(B)\Phi(B^s)W_t = \theta_o + \theta(B)\Theta(B^s)a_t ,$$

where

W_t is $\nabla^d \nabla_d^D z_t'$,

and

z_t' is the transformed time series (for example,

$z_t' = \ln z_t$ or $z_t' = \sqrt{z_t}$) .

The model employs a Marquardt-type [see Ref. 13] non-linear least squares algorithm for determination of the model parameters, searching in the parameter space for the set of parameters which minimizes the sum of the squared model residuals.

A. MATHEMATICAL DISCUSSION OF THE MARQUARDT ALGORITHM

Reference 13 describes Marquardt's methodology for development of a general algorithm for least-squares estimation of nonlinear parameters. Most algorithms for least-squares estimation of nonlinear parameters have been centered about either a pure linear iterative model based on a Taylor series expansion or using some form of the method of steepest descent (maximum negative gradient). Since both methods have severe potential pitfalls (Taylor series due to divergence of the iterates due to an unfortunate choice of initial values, the steepest descent due to slow convergence after the first few iterations), a method termed "Maximum neighborhood" method was developed by Marquardt which, in effect, performs an optimum interpolation between the Taylor series method and the method of steepest descent, the interpolation being based upon the maximum neighborhood in which the truncated Taylor series gives an adequate representation of the nonlinear model.

As discussed in Ref. 14, the idea of Marquardt's method can be briefly explained as follows. Assume the algorithm begins with a vector of initial parameters $(\phi_o, \Phi_o, \theta_o, \Theta_o)$. If the method of steepest descent is applied, a certain vector direction h_g, where the subscript g represents the gradient (which gives the direction in which the rate of change is the greatest), is obtained for movement away from the initial point values in the parameter space. Due to potential nonlinearities in the sum-of-squared-residuals

surface, $S(\phi_o,\Phi_o,\theta_o,\Theta_o)$, in the parameter space, h_g may be the best <u>local</u> direction in which to move toward optimality (minimal sum of squared model residuals), but may not be the best direction. However, the best direction must be within 90 degrees [Ref. 8] of h_g, or else the value of $S(\phi,\Phi,\theta,\Theta)$ will increase locally. Now, the linearization, or Taylor series method, may result in a different correction vector, h_t. Marquardt found experimentally that for a number of practical problems, the angle, say ξ, between the vectors h_g and h_t, fell in the range 80 degrees $< \xi <$ 90 degrees. In other words, the two directions were nearly normal in most cases. The Marquardt algorithm then, provides a method for interpolation between the vectors h_g and h_t, employing a sutiable step size, which, in general, converges more quickly than either of the two "parent" methods alone. The remainder of this section describes the mechanics of the algorithm, as applied to the estimation of Box-Jenkins parameters.

B. MODEL INPUT INFORMATION

The following is the required input information to the WMARQRDT parameter estimation model:

$\{W'_t\}$	the transformed time series (for example, $W'_t = \ln z_t$, or $W'_t = \sqrt{z_t}$
N	the length of the time series
s	the length of the seasonal period (for no seasonality, s = 1)

P	the number of seasonal AR parameters, $P \geq 0$
p	the number of non-seasonal AR parameters, $p \geq 0$
Q	the number of seasonal MA parameters, $Q \geq 0$
q	the number of non-seasonal MA parameters, $q \geq 0$
NDIFNS	the number of non-seasonal differences to be taken
NDIFS	the number of seasonal differences to be taken
$\hat{\Phi} = (\Phi_{1,s},\ldots,\Phi_{P,s})$	initial estimates of seasonal AR parameters
$\hat{\phi} = (\hat{\phi}_1,\hat{\phi}_2,\ldots,\hat{\phi}_p)$	initial estimates of non-seasonal AR parameters
$\hat{\Theta} = (\hat{\Theta}_{1,s},\hat{\Theta}_{2,s},\ldots,\hat{\Theta}_{Q,s})$	initial estimates of seasonal MA parameters
$\hat{\theta} = (\hat{\theta}_1,\hat{\theta}_2, \ldots, \hat{\theta}_q)$	initial estimate of non-seasonal MA parameters

C. ALGORITHM DESCRIPTION

Initially, the model accepts inputs of the time series length and the (transformed, but undifferenced) time series itself from the user's disc, where it is stored in File FT02F001. The remainder of the input data is then entered interactively on the terminal as prompted by the model. The model then forms the initial parameter estimates into vectors of lengths p, P, q, and Q, and employs them to calculate an initial model residual sum of squares.

Prior to initiating the sum of squares calculation process, the model unravels the polynomial of AR and MA operators, and forms a vector of coefficients for both the AR and MA sides of the model. For example, consider the relatively simple $(2,1) \times (2,1)_{12}$ ARIMA model, written

$$(1-\phi_1 B-\phi_2 B^2)(1 - \Phi_{1,12}B^{12})W_t = (1-\theta_1 B-\theta_2 B^2)(1-\Theta_{1,12}B^{12})a_t.$$

Unraveling, the model becomes first:

$$(1-\phi_1 B-\phi_2 B^2)(W_t-\Phi_{1,12}W_{t-12}) = (1-\theta_1 B-\theta_2 B^2)(a_t-\Theta_{1,12}a_{t-12}),$$

and then takes the form:

$$W_t-\Phi_{1,12}W_{t-12}-\phi_1 W_{t-1}+\phi_1\Phi_{1,12}W_{t-13}-\phi_2 W_{t-2}+\phi_2\Phi_{1,12}W_{t-14}$$

$$= z_t-\Theta_{1,12}a_{t-12}-\theta_1 a_{t-1}+\theta_1\Theta_{1,12}a_{t-13}-\theta_2 a_{t-2}+\theta_2\Theta_{1,12}a_{t-14}.$$

This is represented in the computer as four vectors: two vectors, π and γ, composed of the expansion AR and MA coefficients respectively, and two vectors composed of the indices of the time series terms associated with the coefficients. For the model in the example above, these vectors would be written as follows:

$$\pi = (1,\Phi_{1,12},\phi_1,(\phi_1)(\Phi_{1,12}),\phi_2,(\phi_2)(\Phi_{1,12}))$$

$$\text{INDEX}_{AR} = (0,\ 12,\ 1,\ 13,\ 2,\ 14)$$

$$\gamma = (1,\Theta_{1,12},\theta_1,(\theta_1)(\Theta_{1,12}),\theta_2,(\theta_2)(\Theta_{1,12}))$$

$$INDEX_{MA} = (0, \ 12, \ 1, \ 13, \ 2, \ 14).$$

This format for unraveling of a generalized product of polynomials of seasonal and non-seasonal parameters permits simplified calculations in the determination of the sum of squared residuals, since the arithmetic need only be performed for the non-zero parameter values, those contained in the π and γ vectors. In the actual calculations, performed in FORTRAN, the index vector origin is translated to the right by the amount $p + Ps + q + Qs$, called IADDIT in the model, in order to prevent obtaining zero or negative subscripts.

The calculation of the residual sum of squares is a three stage process. First, the model calculates ten values of e_t, the "forward" white noise terms, using the following relationship:

$$e_t = W_t - \sum_{i=2}^{p+Ps} \pi_i W_{t-i} + \sum_{j=2}^{q+Qs} \gamma_j e_{t+j}$$

The assumption is made that $(e_{11}, e_{12}, \ldots, e_N)$ are all equal to zero. Having found the desired values for $(e_{10}, e_9, \ldots, e_1)$, we can now backcast the necessary values of W_t, in order to enable us to calculate the required white noise terms a_t, as follows:

$$W_t = e_t + \sum_{i=2}^{p+Ps} \pi_i W_{t+i} - \sum_{j=2}^{q+Qs} \gamma_j e_{t+j} \quad ,$$

solving for $(W_o, W_{-1}, W_{-2}, \ldots, W_{1-(p+sP+q+sQ)})$. Now, with the W_t's backcast, we can proceed to calculate the estimated white noise terms (residuals) using this relationship:

$$a_t = W_t - \sum_{i=2}^{p+Ps} \pi_i W_{t-i} + \sum_{j=2}^{q+Qs} \gamma_j a_{t-j} \ .$$

The values of a_t are calculated for $t = 1, \ldots, N$. Once the a_t's are calculated, it is a simple matter to calculate the sum of squares, using

$$S(\phi, \Phi, \theta, \Theta) = \sum_{t=1}^{N} a_t^2 \ .$$

Having calculated the residual sum of squares for the initial parameter estimates, we form the parameters into a vector $\hat{\beta}$, such that

$$\hat{\beta} = (\beta_1, \beta_2, \ldots, \beta_k) \ ,$$

where $k = p+P+q+Q$; that is,

$$\hat{\beta} = (\phi_1, \ldots, \phi_p, \Phi_{1,s}, \ldots, \Phi_{P,s}, \theta_1, \ldots, \theta_q, \Theta_{d,s}, \ldots, \Theta_{Q,s}).$$

The subroutine PARSH then calculates the derivatives

$$x_{i,t} = -\frac{\partial a_t}{\partial \beta_i} ,$$

over all values of $t = 1,\ldots,N$ and $i = 1,\ldots,k$. Using the residuals $\{a_t\}$ calculated earlier, the derivatives are estimated numerically using a perturbation of each parameter of amount δ, such that

$$x_{i,t} = \{a_t(\beta_1,\ldots,\beta_k)-a_t(\beta_1,\ldots,\beta_i+\delta,\ldots,\beta_k)\}/\delta .$$

Then with $\{a_t\}$ and $x_{i,t}$ supplied for the current parameter values, the following quantities are formed:

1. The $k \times k$ matrix $A = \{A_{ij}\}$, where

$$A_{ij} = \sum_{t=1}^{N} (x_{i,t})(x_{j,t})$$

2. the vector $G = \{g_i\}$, where

$$g_i = \sum_{t=1}^{N} (x_{i,t})(a_t)$$

3. the scaling quantities $D_i = \sqrt{A_{ii}}$.

Then, the modified (scaled and constrained) linearized equations

$$[A^*]\ [h^*] = [g^*]$$

are formed, where

$$A_{ij}^* = A_{ij}/D_i D_j\ , \quad i \neq j\ ,$$

$$A_{ii}^* = A_{ii}^* + \xi, \quad \xi = .01\ ,$$

and

$$g_i^* = g_i/D_i\ .$$

It can be noted here that the $[A_{ij}^*]$ matrix is in fact a correlation matrix for the model parameters. Those equations are then solved for h^*, which is scaled back to give the parameter correction vector h_j, where

$$h_j = h_j^*/D_j\ .$$

Then, the new parameter values are formed from the h vector, such that

$$\beta_{NEW} = \beta_{OLD} + h\ ,$$

and the sum of squared residuals for the β_{NEW} set of parameters is calculated.

Now, if $S(\beta_{NEW}) < S(\beta_{OLD})$, the parameter corrections h are tested. If all elements of the h vector are smaller than some epsilon, say .0001, then convergence is assumed and the k x k matrix $[A^*]^{-1}$ is used to calculate the covariance matrix of the estimates; otherwise, β_{OLD} is reset to β_{NEW}, the constant ξ is reduced by a factor F, say .1, and computation returns to the calculation of a new set of derivatives.

However, if $S(\beta_{NEW}) > S(\beta_{OLD})$, the constraint parameter ξ is increased by the factor F, and computation is returned to the stage where the A matrix is formed. In all but unusual cases, a minimal sum of squares will be found. However, an upper bound can be placed on ξ, and when it is exceeded, the search is terminated. When convergence is reached, the desired output information is calculated.

D. MODEL OUTPUT AND DIAGNOSTIC CHECKS

The output includes:

1. $\beta = (\beta_1,\ldots,\beta_k)$ the least-squares estimates of

$$\phi_1,\ldots,\phi_p$$
$$\Phi_1,\ldots,\Phi_P$$
$$\theta_1,\ldots,\theta_q$$
$$\Theta_1,\ldots,\Theta_Q$$

2. $\hat{\sigma}_a^2$ the residual variance, $\frac{1}{N-p-q-P-Q} S(\hat{\phi},\hat{\Phi},\hat{\theta},\hat{\Theta})$

3. V the covariance matrix of the parameter estimates, formed from

$$V = \{V_{ij}\} = (A^T A)^{-1} \hat{\sigma}_a^2$$

4. s_i the standard errors of the parameter estimates,

$$s_i = \sqrt{V_{ii}} , \quad i = 1,\ldots,p+q+P+Q$$

5. R_{ij} the correlation matrix, obtained from

$$R_{ij} = V_{ij} / \sqrt{V_{ii} V_{jj}}$$

6. $\hat{\theta}_o$ the overall constant term, where $\hat{\theta}_o = \hat{\mu}\, G$, for

$$G = (1 - \sum_{i=1}^{p} \hat{\phi}_i)(1 - \sum_{j=1}^{P} \hat{\Phi}_j) \quad \text{and}$$

$$\hat{\mu} = \frac{1}{N} \sum_{t=1}^{N} w_t$$

Finally, diagnostic checks on the model are performed. This includes calculation of residual autocorrelations $r_{\hat{a}\hat{a}}(k)$, obtained from these formulas:

$$r_{\hat{a}\hat{a}}(k) = c_{\hat{a}\hat{a}}(k)/c_{\hat{a}\hat{a}}(0) ,$$

where

$$c_{\hat{a}\hat{a}}(k) = \frac{1}{N} \sum_{t=1}^{N-k} (\hat{a}_t - \bar{a})(\hat{a}_{t+k} - \bar{a}) ,$$

$$\bar{a} = \frac{1}{N} \sum_{t=1}^{N} a_t ,$$

and k goes from 1 to the maximum desired lag K, usually 40. Additionally, a chi-square statistic is calculated from

$$\chi^2_{(\nu)} = N \sum_{k=1}^{K} r^2_{\hat{a}\hat{a}}(k) ,$$

and is compared with a chi-square distribution with $\nu = K - p - q - P - Q$ degrees of freedom.

Examples of input methodology and appearance of output for this model are contained in later chapters of this paper.

IV. DESCRIPTION OF THE TIME SERIES EDITOR

In this chapter, descriptions are given for each of those programs in the Time Series Editor which interact with the user. There are fifteen separate program modules currently included in the Editor; there are other programs utilized by the Editor that are completely transparent to the user, and are not described here. However, listings for all programs contained in the Editor are provided in Appendix D to this report.

No attempt is made in this chapter to describe the actual mathematical calculations or algorithms that are performed by the programs. Rather, the objective is to provide general descriptions of what each program can do for the user, and how the user interacts with the programs. The programs described in this chapter are, in the order presented: TIMESER EXEC, ZFORMAT, CMSWORK, TRANS, DIFF, PLOT, AUTO, ESTIMATE, YESTSEAS, WMARQRDT, XSUMSQ, FORECAST, ROOTS, SIMULATE and GENERATE, and HELP.

A. THE EXECUTIVE PROGRAM

The heart of the Time Series Editor is a master program called TIMESER EXEC which provides file control for all of the other program modules, controls input and output, supervises the necessary CP/CMS protocol and provides instructions interactively to the user concerning the contents of the

Time Series Editor and how each program can be used.
The TIMESER EXEC program is written in the IBM-360 CP/CMS Executive language. It is the only program in the package not written in FORTRAN; consequently, it should be the only program that would need modification if the Editor were to be adapted to another FORTRAN-capable time-sharing system.

After the user has logged into CP/CMS and linked to the disc space containing the Time Series Editor (instructions for this procedure are provided in detail in the User's Guide to the Time Series Editor, included as Appendix A to this report), the entire Editor package is made available to the user by the command TIMESER. On entry of this comand, the executive routine, TIMESER EXEC, can provide a guided tour through the Editor. It will briefly describe what the Editor can provide and asks the user what option he wants to use. On the basis of the user's response, the Editor then advises the user what input data is required and how it should be entered, either through a data file entered offline or parametric data entered interactively at the terminal. When the user selects an option for execution, the TIMESER EXEC routine loads the appropriate program package and automatically manipulates the required input and output data files. For the more experienced user who does not require detailed user instructions, there is a shortened version of the TIMESER EXEC. Upon entry into the shortened version, the user is immediately asked which

option he desires. This version of the Editor is entered by adding the argument "s" when logging into the Editor; that is, type TIMESER S when logging in. The TIMESER S (shortened) version of the Editor provides exactly the same program options to the user as the longer TIMESER version.

B. DATA AND FILE MANAGEMENT

Whenever data is required, the user is prompted at the terminal by either the TIMESER EXEC or the program module being executed. In most cases, the necessary user response is a short alphanumeric character input during execution using the terminal keyboard. However, when the time series data itself is entered, the user may enter the data by card deck offline. Similarly, most output is provided right at the user's terminal. Output such as listings of transformed series or plots are sent to the offline printer to conserve time and provide hard copies of the results. Detailed descriptions of the input and output requirements of each program module are provided in this chapter, and also in abbreviated tabular form in Appendix A, the User's Guide. However, there are some general principles of data management that apply to all programs. These are described in this section.

1. Offline Data Entry

The Time Series Editor requires that the user's time reside in FILE FT02F001. The data can be read offline

via cards and directed to FILE FT02F001. An example of the required format for the input card deck for the Time Series Editor is provided in Figure 5. It is noted here that the data format expected by all programs is FORMAT(5F15.6), preceded by a card containing the length of the time series in FORMAT(I3).

2. ZFORMAT Program

In many cases, the user will want to analyze time series data that are already available ina format other than that required by the Editor. To spare the user the tedious task of retyping his deck in the required format, the ZFORMAT program was written. This program converts a time series data file (FILE FT03001) written in any FORTRAN format into the proper FORMAT(5F15.6) onto FILE FT02F001. The length of the series is entered as an input on the terminal. The data are then ready to use in the Editor, with the original file left in FILE FT03F001. Figure 6 shows a sample input deck for such non-standard data. Figure 7 gives a sample session where ZFORMAT is used.

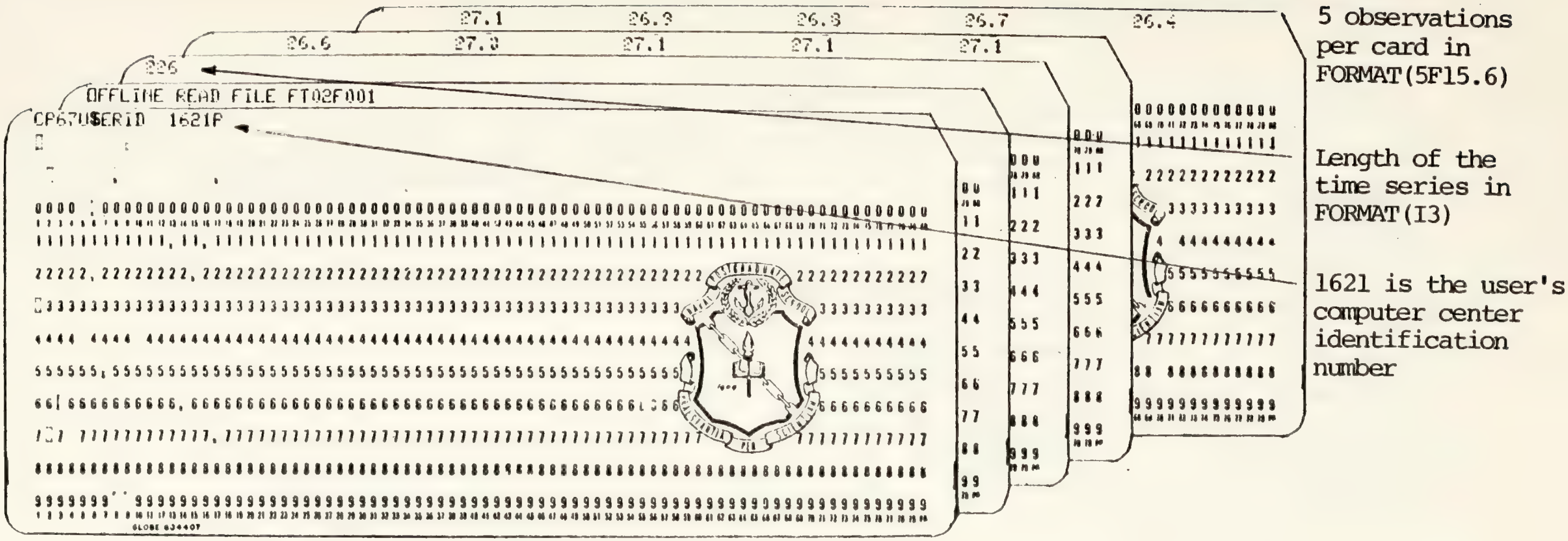


Figure 5. Card deck arrangement for OFFLINE READ of time series input data in FORMAT(5F16.5)

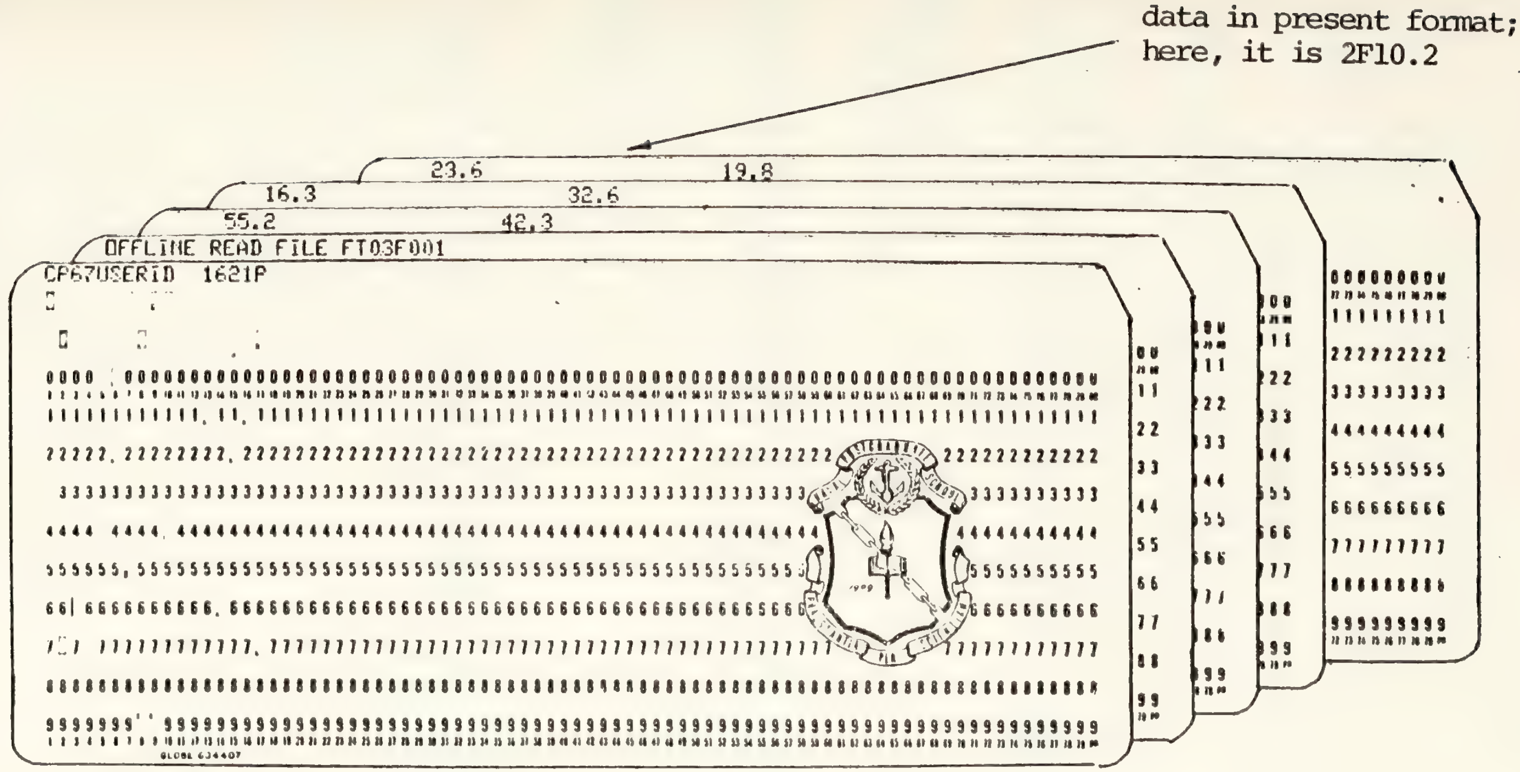


Figure 6. Card deck arrangement for OFFLINE READ of time series input data in any FORMAT

```
timeser s

ENTER LETTER FOR OPTION YOU WANT.
z
IS YOUR DATA IN FILE FT03F001?
y
EXECUTION BEGINS...

 IS YOUR TIME SERIES DATA NOW IN FILE FT03F001?
y

 ENTER THE LENGTH OF YOUR TIME SERIES VIA FORMAT I3.
010

 NOW ENTER THE FORTRAN FORMAT FOR YOUR TIME SERIES DATA,
 INCLUDING PARENTHESES; FOR EXAMPLE, TYPE: (5F15.7).
f10.2

 YOUR FORMAT IS:
 FORMATF10.2
 IS THIS CORRECT?
n

 NOW ENTER THE FORTRAN FORMAT FOR YOUR TIME SERIES DATA,
 INCLUDING PARENTHESES; FOR EXAMPLE, TYPE: (5F15.7).
(f10.2)

 YOUR FORMAT IS:
 FORMAT(F10.2)
 IS THIS CORRECT?
y

 YOUR DATA IS NOW TRANSFORMED INTO THE PROPER FORMAT
 FOR USE IN THE TIME SERIES EDITOR,LOCATED IN FILE
 FT02F001. YOUR ORIGINAL DATA IS IN FILE FT03F001.

DO YOU WANT TO GO AGAIN?
n
CONTROL RETURNED TO CMS
R;
```

Figure 7. Sample user session with ZFORMAT program

3. Interactive Keyboard Input

a. Numeric Input

When the user is prompted at the terminal to enter such numerical values as the number of AR parameters, estimates of parameters or the number of differences to be taken, he must enter these values before program execution can continue. The user should enter the data according to standard FORTRAN practice. For example, integer data should be entered (without a decimal point) for counts, such as the length of a seasonal period, and for names beginning with the letters I through N; floating-point data, such as initial estimates of parameters, should be entered with a decimal point. Because a typed decimal point overrides a floating-point format, it is not necessary for the user to concern himself with the format for floating-point input data. However, care must be taken when entering integer data because it must be right-justified in its format field. The user is advised in each case when the format is other than I1. For example, suppose the user desires to perform analysis on a series having only 90 observations. If the program that he is executing requires the length of the time series, the user will receive the following request:

```
ENTER LENGTH OF THE TIME SERIES VIA FORMAT I3
```

The user would then enter:

column 123

b90 (where b represents a blank space).

If the blank were omitted, the program would read the series length as 900, and problems in execution would occur.

b. Alphabetic Input

The Editor often asks the user to respond with alphabetic input. Generally, this is in the form of the response to a question requiring a yes or no answer, or a response to the question of which program to execute. The editor has been programmed to read only the first letter of such responses. Therefore, the user need only enter the first letter of the response for each such inquiry. For example, the user should enter Y for yes, N for no, P for the PLOT option, X for the XSUMSQ option, W for the WMARQRDT option, etc. The other alphabetic input is generally entry of titles to plots; these can be any combination of numeric and alphabetic characters, as long as they do not exceed 72 columns in length. For example, a suitable title would be:

PLOT OF AUTOS AND PAUTOS FOR SERIES C DATA (2 ORDINARY DIFFERENCES).

4. Output

Most of the results are written out at the user's terminal. However, in some cases the output is printed

offline to conserve time. Such results as plots and transformed time series are written onto various files (FT03F001, FT09F001, FT08F001), and the TIMESER EXEC program causes them to be automatically printed offline under the user's identification number (USERID). The plots and files can also be printed out at the terminal using the usual CMS commands in the CMS mode, outside the Editor, or in the CMSWORK program (see next section). However, the user should be aware that plotting graphs at the terminal is generally quite a slow process.

5. CMSWORK Program

This program permits the user to enter the CMS environment to perform routine CMS functions without leaving the Time Series Editor. Commonly used CMS commands include file name alteration, file erasure, file offline printing or punching, obtaining a disc status, and listing all disc-resident files. However, essentially all CMS commands can be issued while in CMSWORK. Figure 8 provides an example of the use of the CMSWORK program.

C. TRANS PROGRAM

The TRANS program takes a given time series in File Fl02F001 and performs a transformation upon each data element. The options include a change of scale, a power transformation, a shift of the origin, and a natural logarithm transformation. The original data is written onto a file

```
timeser s

ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
stat
P (191): 30 FILES; 263 REC IN USE, 33 LEFT (of 296), 89% FULL (2 CYL)
listf * ft02f002
FILE NOT FOUND
17.14.13 LISTF * FT02F002
 !!! E(00002) !!!
listf * ft02f001
FILENAME FILETYPE MODE NO.REC. DATE
SERG     FT02F001  P1      3    9/16
SERC     FT02F001  P1      5    9/16
LNSERG   FT02F001  P1      3    9/16
FILE     FT02F001  P1      3    9/16
cp q f
FILES:- NO RDR, NO PRT, NO PUN
erase file ft08f001
offline print file ft02f001
offline print serg ft02f001
offline print serc ft02f001
erase file ft02f001
stat
P (191): 28 FILES; 240 REC IN USE, 56 LEFT (of 296), 81% FULL (2 CYL)
&goto -ques
DO YOU WANT TO GO AGAIN?
n
CONTROL RETURNED TO CMS
R;
```

Figure 8. Sample user session with CMSWORK program

called DATA FT02F001, while the transformed series is written onto FILE FT02F001. The parameters of the transform itself are written onto FILE FT07F001. The TRANS program is self-contained, using no other programs.

D. DIFF PROGRAM

The DIFF program takes a given time series in FILE FT02F001, and performs non-seasonal and/or seasonal differencing operations on the series in order to help achieve stationarity for proper modeling. The user must indicate if seasonal differences are required; if so, the length of the season is input. The user is then required to enter the number of seasonal and nonseasonal differences. After execution of DIFF, the original data are in FILE FT02F001, and the differenced data are written onto FILE FT03F001. To use the differenced data in any other program, CMSWORK program must be entered and the files altered to save the original data (if desired) and to transfer the differenced data to FILE FT02F001. The CMS commands to perform this shift of files would look like:

```
    ALTER FILE FT02F001 P1 SAVEDATA FT02F001 P1
    R;
    ALTER FILE FT03F001 P1 FILE FT02F001 P1
    R;
```

The DIFF program uses the IMSL subroutine called FTRDIF.

E. PLOT PROGRAM

The PLOT program plots any given time series which resides in FILE FT02F001. Other than the time series, which must be on the user's disc or entered offline, the program requires only that an identification title for the plot itself be entered during execution. The plot is automatically printed offline. The PLOT program uses a modified PLOTP subroutine called PLOT8 from the IBM Scientific Subroutine Package Library (SSPLIB).

F. AUTO PROGRAM

The AUTO program takes a given time series in FILE FT02F001 and calculates summary statistics of utility in Box-Jenkins modeling. The statistics include the sample mean, variance, autocorrelations and partial autocorrelations for lags one though 40. Part of those statistics are printed out at the user's terminal, while plots of the autocorrelations and partial autocorrelations versus lag are printed offline. These plots will also be written onto the user's disc in FILE FT08F001, and may be plotted at the terminal in CMS outside the Editor or in the CMSWORK program; recall that this is a time-consuming process. The AUTO program provides the user with essential information about stationarity, seasonality and model identification. With the Box-Jenkins procedures, the second moments (autocorrelations and partial autocorrelations) are valuable tools in tentative model identification. Additionally, AUTO

is useful in the diagnostic checkout phase of model building, when examining the model residuals for structure. The AUTO program uses the IMSL subroutine FTAUTO.

G. ESTIMATE PROGRAM

After the user has tentatively identified a model for a series through analysis of the series plot, autocorrelations and partial autocorrelations, ESTIMATE should be executed to calculate maximum likelihood estimates of the model parameters. ESTIMATE is written to calculate parameters for non-seasonal models only; for seasonal models, the programs YESTSEAS and WMARQRDT should be used for parameter estimation. The ESTIMATE program requires that the series to be modeled (already transformed and differenced to achieve stationarity) reside in FILE FT02F001; additionally, the program will instruct the user to input the number of MA and AR parameters in the model, as well as the number of differences taken. The general model for which ESTIMATE calculates parameters is:

$$\phi(B)\ W'_t \ = \ \theta_o + \theta(B)\ a_t$$

where $W'_t = \nabla^d z'_t$ and z'_t is the transformed value of z_t. ESTIMATE calculates estimates of the AR parameters for the undifferenced form of the model, the estimated MA parameters and MA constant term, the residual variance, autocorrelations and partial autocorrelations of the residuals, plots of

these autocorrelations and partial autocorrelations, and a Chi-square goodness-of-fit statistic for the model. The original series to be modeled remains in FILE FT02F001 and the residuals of the model are stored in FILE FT02F001. ESTIMATE uses the IMSL subroutine FTMAXL (a nonlinear gradient search algorithm) to estimate the model parameters.

H. YESTSEAS PROGRAM

The YESTSEAS program is used to calculate initial estimates of autoregressive and moving average parameters for a generalized seasonal Box-Jenkins model. These initial estimates are used as inputs to the program WMARQRDT, which then refines them to determine the parameter estimates that minimize the sum of the squared residuals. The general model assumed in YESTSEAS is

$$\phi(B)\,\Phi(B^s)\,\nabla^d \nabla_s^D z_t \;=\; \theta(B)\,\Theta(B^s)\,a_t \;.$$

The YESTSEAS program requires that the seasonal time series for which initial parameter estimates are required is located in FILE FT02F001; it should be transformed, if desired, but generally not differenced, since YESTSEAS performs the required (seasonal and/or non-seasonal) differencing. Terminal inputs required by the program include the number of sdasonal and non-seasonal differences to be taken (if data is already differenced, enter zero for these values), the length of the seasonal period and the number of each

type of parameter to be estimated (that is, the number of each of the seasonal and non-seasonal AR and MA parameters). The output of the model, initial estimates for the requested parameters, is printed out at the terminal. YESTSEAS uses the IMSL subroutines FTRDIF, FTMAXL, FTAUTO and FTARPS, as well as a modified version of FTMAPS.

I. WMARQRDT PROGRAM

The WMARQRDT program uses the initial parameter estimates calculated by YESTSEAS or other means as starting points for calculation of parameters of a generalized seasonal Box-Jenkins model which minimize the sum of the squared residuals. The general seasonal model assumed by WMARQRDT can be written:

$$\phi(B)\Phi(B^s)\nabla^d\nabla_s^D z_t = \theta_o + \theta(B)\Theta(B^s)a_t.$$

Details of the Marquardt-type non-linear least squares algorithm employed in this program are provided in Chapter III of this report. WMARQRDT requires that the series to be modeled reside in FILE FT02F001; it should be transformed, if desired, but generally not yet differenced, since the program performs differencing. Inputs at the terminal include number of seasonal and non-seasonal differences, length of the seasonal period, number and type of parameters desired, and initial estimates of those parameters. The program then calculates the least-squares parameter estimates,

the standard error of these estimates, the MA constant term, the residual variance, the autocorrelations and partial autocorrelations of the residuals, the final model sum of squared residuals and a Chi-square goodness-of-fit statistic (the portmanteau test). Additionally, it plots offline the autocorrelations and partial autocorrelations of the residuals. WMARQRDT uses the IMSL subroutines FTRDIF, FTAUTO, LINV1F and MDCDFI, the SSPLIB routine PLOT8, and the Time Series Editor resident subroutines PARSH, MARQRT, SUMSQ, SWAPB and FORMB. The calculations are performed in double-precision arithmetic.

J. XSUMSQ PROGRAM

The XSUMSQ program accpets an already transformed and differenced series in FILE FT02F001 and general seasonal and non-seaonal Box-Jenkins parameter values for a general seasonal model from the terminal. The program then calculates the residual sum of squares for these parameters, giving the user a feel for the "goodness-of-fit" the parameter estimates provide in modeling the given time series. XSUMSQ uses the Time Series Editor resident subprogram XSUMSQ. All output is printed at the terminal. The calculations are performed in double-precision arithmetic.

K. FORECAST PROGRAM

The FORECAST program uses the estimated Box-Jenkins (seasonal or non-seasonal) model to compute forecasts of

the transformed and differenced time series. FORECAST requires that the time series to be forecasted reside in FILE FT02F001 in transformed form. During execution the input required at the terminal includes the forecast origin, the numbers and estimated values of the AR and MA parameters of the model, the overall MA constant, the plot origin index, the maximum forecast lead time, the order of differencing in the model, and a level of significance for the forecast confidence limits. The program needs the transformation parameters from FILE FT07F001, created when using program TRANS, and performs the inverse transform to return the data to its original form. FORECAST also undifferences differenced data. The program output includes the forecasts up to the given maximum lead time, the deviations from each forecast for the confidence limits, and plots of forecasts and confidence limits plotted offline. The FORECAST program uses IMSL subroutine FTCAST and the special IBM SSPLIB subroutine UTPLT8. The plot itself and output data are written onto FILE FT08F001 on the user's disc; since this plot file takes considerable space, it is usually best to erase it after execution of the program is completed and the plot itself has been printed offline.

L. ROOTS PROGRAM

The ROOTS program is used to determine the roots of the characteristic equation for a general ARIMA model. The roots are useful for testing for stationarity and for

determining the form of the forecast function. ROOTS uses the IMSL subroutine ZPOLR to calculate the roots; it requires as input the number of AR parameters in undifferenced form,[1] and the actual values of these parameters, as determined from the ESTIMATE or WMARQRDT programs. The roots are printed out at the terminal. If desired, roots can also be obtained for the MA polynomial, simply by substituting the appropriate MA values for the AR values as input.

M. GENERATE AND SIMULATE PROGRAMS

Because of their similarities, the GENERATE and SIMULATE programs are described together. The GENERATE program permits the user to generate a time series from any non-seasonal ARIMA model he specifies. The user must identify the model and give values for the model parameters and starting conditions; a random number seed must also be input. The program takes the specified model, generates random noise terms, and calculates as many values of the time series as desired. The GENERATE program can be useful for purposes of classroom instruction in the generation of a wide variety of time series examples for model identification exercises.

---

[1]Suppose the model was ARIMA(1,1,0). The differenced form would be $(1-\phi_1 B)\nabla^1 z_t = \theta_o + a_t$. Then, the undifferenced form would be written $(1-(1+\phi_1)B + \phi_1 B^2)z_t = \theta_o + a_t$, where the left-hand side was found by multiplying $(1-\phi_1 B)$ by $(1-B) = \nabla^1$.

It could also be useful in the diagnostic phase of model checkout; a time series could be generated from the estimated model, and its properties compared with those of the original series. If large discrepancies occur in this comparison, this may be evidence that the model is inadequate. The model output, the generated time series, is written in FILE FT02F001 as well as being printed offline. The GENERATE program uses IMSL subroutine FTGEN1.

The SIMULATE program provides the capability of generating any number of simulated time series. This program is useful for prediction of what might happen in the future; it also demonstrates that within a given model, the time series actually observed can vary considerably. This program uses GENERATE, but also requires as input the actual series in FILE FT02F001[1] and the number of simulated series the user wishes to generate. The series should be already transformed and differenced. Additionally, SIMULATE allows the user to select values of the original time series as starting values for the simulated series. The output consists of the simulated series printed at the terminal. The SIMULATE program uses IMSL subroutine FTGEN1.

N. HELP OPTION

The HELP option is a modification to the Time Series Editor CP/CMS program itself that allows the user to obtain

---

[1]If desired, the user may choose to input his own starting values, and not use the actual time series values.

information about Editor programs after the initial introductory phase has been completed.

O. SUMMARY

This chapter has provided brief descriptions of the options available for analysis of time series data in the Time Series Editor. The following two chapters contain detailed examples of time series analysis for both a non-seasonal and a seasonal series; the accompanying terminal sessions and computer output for analysis of these series are contained in full in Appendices B and C. Appendix A to this report contains a User's Guide for the Time Series Editor, while Appendix D contains a complete listing of the Time Series Editor and resident programs. Appendix E contains listings of the data sets used in the analyses of the next two chapters.

V. EXAMPLE NON-SEASONAL TIME SERIES ANALYSIS

This chapter provides a description of a complete analysis of a non-seasonal time series using the Time Series Editor. The time series analyzed is Series C (Chemical Process Temperature Readings), taken from Box and Jenkins [Ref. 4, p. 528]. This time series was selected since it is fully analyzed and discussed in Reference 4, so that the interested user can compare for himself the results presented there with the results given by the Time Series Editor. After reading this overview of the analysis, the reader can follow the actual user session and associated user session Editor program output contained in Appendix B to this report.

The first step in the analysis of series C is to plot the series using program PLOT. The plot reveals rather wide fluctuations in the series, but not the sort of explosive nonstationary behavior that would render an attempt to model fruitless. The plot also reveals that the time series has a large amount of momentum (movements of the series tend to resist changes of direction over time). This is characteristic of ARIMA models with two or more differences.

As a second step, the autocorrelations (autos) and partial autocorrelations (pautos), mean, and variance of the series were estimated using AUTO. The plot shows that the autos dampen out slowly in a nearly linear fashion.

This is an indication that the process is nonstationary and that one or more differences are required to make it stationary. The pauto plot is not informative when the autos fail to dampen out rapidly.

As suggested by the plots of the original series and its auto and pautos, the program DIFF was used to examine the series with both one and two non-seasonal differences; i.e., the series $z_t' = \nabla^1 z_t$ and $z_t'' = \nabla^2 z_t$ were derived. The plots suggest that two differences might be required to achieve stationarity in the series. However, one might be able to get by with a single difference and an AR parameter near unity, since the autos of z_t' dampen out slowly. Thus, two possible model candidates are suggested:

1. ARIMA(1,1,0): $(1 - \phi_1 B)\nabla^1 z_t = \theta_o + a_t$,

and

2. ARIMA(0,2,2): $\nabla^2 z_t = \theta_o + (1 - \theta_1 B - \theta_2 B^2) a_t$.

For purposes of estimation, the second model was extended to two moving average parameters. Such overfitting is often done to see if the estimated moving average parameters turn out to be near zero, thus confirming the tentative identification.

The next step in the analysis process is to calculate the maximum likelihood estimates of the model parameters.

The program ESTIMATE was used to do this. The estimated parameters for the ARIMA(1,1,0) model were:

$$\hat{\phi}_1 = 0.8073$$
$$\hat{\theta}_0 = -0.006789$$
$$\hat{\sigma}_a^2 = 0.0177633$$

The autos and pautos of the residuals were calculated to test the model. The correlations should appear to be estimates of a pure white noise process if the model is adequate; the (1,1,0) model seemed to pass that test. The chi-square goodness-of-fit test results in a $\chi^2 = 28.88$ with 24 df and a signficance level of 0.2247. Thus, there is no strong evidence tc suggest that the (1,1,0) model is inadequate. The model can be written, in undifferenced form:

$$(1 - 1.8073B + 0.8073B^2)z_t = a_t .$$

The θ_o is omitted here since it is nearly zero in value.

The estimated parameters for the (0,2,2) model were

$$\hat{\theta}_1 = 0.1378$$
$$\hat{\theta}_2 = 0.1296$$
$$\hat{\theta}_o = -0.0026787$$
$$\hat{\sigma}_a^2 = 0.0189559$$

As before, the correlation plots of the residuals fail to suggest any inadequacy of the model. However, the chi-square goodness-of-fit test for this model yielded a $\chi^2 = 36.75$ with 23 df and a significance level of 0.0346. Therefore,

if the ARIMA(0,2,2) model were a "correct" one, a chi-square value as large as 36.75 would occur by chance with a probability of only 0.0346. Due to its simplicity (parsimony is a desirable feature in time series models) and better fit, the ARIMA(1,1,0) model was chosen as the "best" of the two alternatives originally selected.

The ARIMA(1,1,0) model calculated was then used to make forecasts and confidence limits for these forecasts, using program FORECAST. The forecasts were made for 25 periods into the future, with plot origin 200 and forecast origin 220. The length of the series C itself is 226; with one difference, it becomes 225. The plot in Appendix B shows the forecasted values, along with the confidence limits at level of significance 0.10; the plot shows that the width of the confidence limits increases substantially as the lag gets large.

Finally the program ROOTS was used to calculate the roots of the characteristic equation for the ARIMA(1,1,0) model, which can be written:

$$1 - 1.8073B - 0.8073B^2 = 0$$

The roots calculated by ROOTS were 1.239 and 1.0. Also, the program SIMULATE was used to generate a simulated series from the ARIMA(1,1,0) model, using the last two values of the actual series as starting values. The entire session lasted about two hours, including checkout of plots and consumed less than a minute of CPU time.

VI. EXAMPLE SEASONAL TIME SERIES ANALYSIS

This chapter provides a description of a complete analysis of a seasonal time series using the Box-Jenkins technique through the Time Series Editor. The time series analyzed is Series G (International Airline Passengers: Monthly Totals (Thousands of Passengers) January 1949 - December 1960), taken from Box and Jenkins [Ref. 4, p. 531]. This time series was selected since it was fully analyzed and discussed in Chapter 9 of Reference 4; again, the interested reader can compare for himself the results presented by Box and Jenkins with those given by the Time Series Editor programs. After reading this overview of the analysis, the reader can follow the actual user session and associated Editor program output contained in Appendix C to this report.

The plot shows both annual seasonality and an increasing trend. This suggests that a seasonal model with differencing may be needed. The autocorrelations (autos) and partial autocorrelations (pautos) were then calculated and plotted using AUTO. The plot of the autos shows very slow damping out with peaks at intervals of 12, indicating strong nonstationarity and a seasonal period of 12 months. Again, here the pauto plot is not informative, due to the slow damping out of the autos. As it is sometimes useful in dealing with seasonal models, a natural log transform was

made on the series G data using program TRANS. The plot of the logged data shows little change in non-stationarity, and the autos and pautos of the logged data still indicate seasonality and non-stationarity.

Next, differencing to achieve stationarity was tried, using program DIFF; both one seasonal and one non-seasonal difference of the logged data was taken. The autos and pautos of the data $\nabla^1\nabla^1_{12}$ (ln z_t) appear much improved, rapidly damping out. They also exhibit sharp peaks at the periods of seasonality, indicating the need for seasonal parameterization in the model. Since positive identification of the model type from the auto and pauto plots was not possible, two were postulated as close candidates:

1. ARIMA $(0,1,1) \times (0,1,1)^{12}$, written:

$$\nabla^1\nabla^1_{12}(\ln z_t) = \theta_o + (1-\theta_1 B)(1-\Theta_{1,12}B^{12})a_t ,$$

and

2. ARIMA $(1,1,1) \times (0,1,1)^{12}$, written:

$$(1-\theta_1 B)\nabla^1\nabla^1_{12}(\ln z_t) = \theta_o + (1-\theta_1 B)(1-\Theta_{1,12}B^{12})a_t .$$

The next step in the analysis was to calculate the parameter estimates for both models. YESTSEAS was used to

obtain initial parameter estimates. For the model ARIMA $(0,1,1) \times (0,1,1)^{12}$, YESTSEAS yielded starting values:

$$\hat{\theta}_{1(s)} = 0.390425$$

$$\hat{\Theta}_{1,12(s)} = 0.534397 \text{ .}$$

For this model, calculation of final parameter estimates in WMARQRDT using the starting values above yielded the following in seven iterations:

$$\hat{\theta}_1 = 0.377152$$

$$\hat{\Theta}_{1,12} = 0.572387$$

$$\hat{\theta}_o = 0.000291 \text{ ;}$$

the chi-square statistic for residual lack of fit of the model was $\chi^2 = 29.713571$, with df = 38 and a probability of exceeding the χ^2 value of .829.

For the ARIMA $(1,1,1) \times (0,1,1)^{12}$ model YESTSEAS calculated starting values:

$$\hat{\phi}_{1(s)} = 0.112699$$

$$\hat{\theta}_1(s) = 0.490883$$

$$\hat{\Theta}_{1,12(s)} = 0.533679 \;;$$

for this model, WMARQRDT yielded the following parameter values in ten iterations:

$$\hat{\phi}_1 = 0.146667$$

$$\hat{\theta}_1 = 0.509816$$

$$\hat{\Theta}_{1,12} = 0.573388 \;.$$

The chi-square statistic for residual lack of fit of the model was $\chi^2 = 28.302543$, with df = 37 and a probability of exceeding the χ^2 value of .847.

Next, the plots of autos and pautos of the residual for both models were examined; both models have autos and pautos that dampen out rapidly, and essentially appear to be "white noise", with the exception of a small peak at auto and pauto of lag 12, corresponding to the seasonal period. The chi-square statistics indicate that both models have "about" the same goodness of fit to the data. Consequently, both models were used to make forecasts of the series.

Program FORECAST was used to forecast series G into the future for 30 time periods, with a forecast origin of 131; the plot origin selected was index 100. As expected, both models do about the same job of forecasting the series.

The significance level for the confidence limits for both plots was 90%.

As a final check of both models, the program XSUMSQ was used to calculate the sum of squared residuals for models. The results were as follows:

1. For ARIMA $(0,1,1) \times (0,1,1)^{12}$,

$$S^2(\hat{\theta}_o, \hat{\theta}_1, \hat{\Theta}_{1,12}, \hat{\sigma}_a^2) = 0.181929$$

2. For ARIMA $(1,1,1) \times (0,1,1)^{12}$,

$$S^2(\hat{\phi}_1, \hat{\theta}_o, \hat{\theta}_1, \hat{\Theta}_{1,12}, \hat{\sigma}_a^2) = 0.181643 .$$

It can be seen here that both models are nearly equally "good", and either could be used with a reasonable amount of confidence for forecasting series G.

VII. SUMMARY

There has been an increasing need in military applications, as well as in the general business area, for a computer-aided time series analysis and forecasting capability that is both powerful and easy to use. Current military-associated functions in which time series techniques are valuable include material inventory management, recruiting, personnel management, budget analysis, force level projections, and perhaps even short-term weather prediction.

The Time Series Editor that has been described in this report provides a unified collection of programs that greatly facilitate the conduct of a complete time series analysis and forecasting evolution using Box-Jenkins methodology. The routines guide the user from the data input stage, through the data analysis and parameter estimation stages, and finally through the model building, diagnostic checking and forecasting stages. With its simple input requirements, the Editor can be quickly mastered by even a beginning computer user, who has a basic understanding of Box-Jenkins methodology.

The Box-Jenkins methodology has been described broadly in Chapter II and descriptions of the programs resident in the Time Series Editor have been given in Chapter IV. Example analyses of both non-seasonal and seasonal time series are provided in Chapters V and VI, with complete

user sessions and output packages for these analyses included as Appendices B and C. The Appendices also contain a Time Series Editor User's Guide, as well as complete program listings.

Although the Time Series Editor in its present form provides an excellent capability for interactive time series analysis using the Box-Jenkins methodology, there are additions to the program set that might be made in the future which would improve the Editor's capability and utility. It is first recommended that the model diagnostic testing capability be extended to include a periodogram analysis, and/or other tests related to the spectral analysis of time series [see Ref. 4, p. 294]. Another useful addition might be to include in the Time Series Editor a package capable of improving the ease of entering data and simplifying the input error correction problem.

APPENDIX A

USER'S GUIDE TO THE TIME SERIES EDITOR

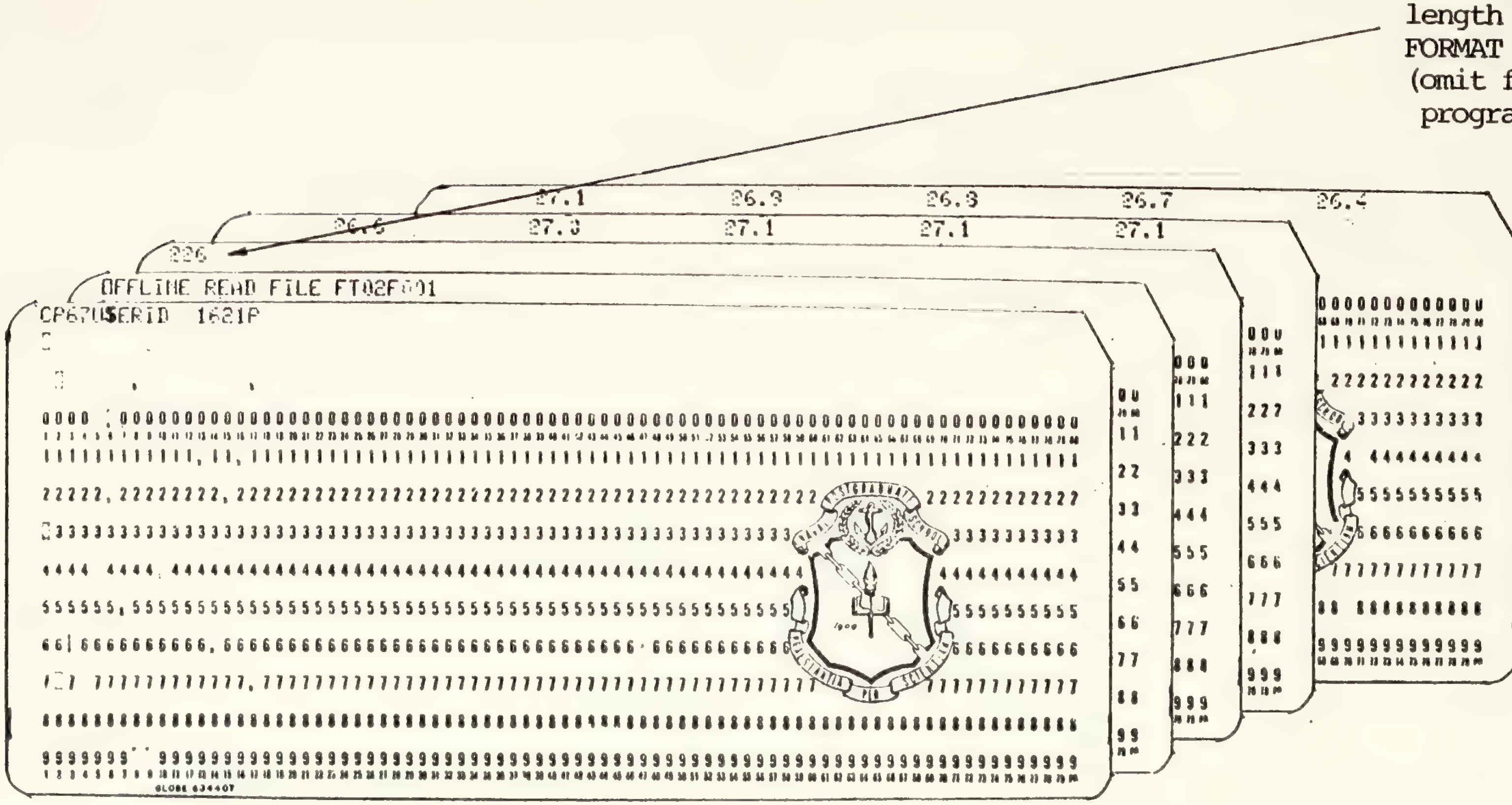
The Time Series Editor is a collection of FORTRAN programs driven by a control program called TIMESER EXEC in the CP/CMS executive language that has been designed specifically for the analysis and forecasting of time series data using the general Box-Jenkins methodology. This Guide contains information essential for the user to access the Time Series Editor, enter time series data, build a model and obtain the desired output.

I. DATA INPUT

The Time Series Editor requires that time series data be entered into the sequential FORTRAN input/output file named FILE FT02F001. This can be done either online or via cards read offline. The following diagram illustrates the proper card deck arrangement. When your deck is ready for input, give it to a computer center system operator to direct it to your disc space.

If the user has a data deck already punched up in a format other than 5F15.6, he may enter the series as above into FILE FT03F001 (without the length of series card) and use the Editor program ZFORMAT to transform it into the FILE FT02F001 in the proper format, without destroying his original file. This program is described in the next section.

DATA ENTRY DECK



II. TABLE OF OPTIONS

This Table provides the user with the basic information necessary to understand the data requirements, functions and output options for each program in the Editor.

PROGRAM	INPUT	OUTPUT	REMARKS
Name: ZFORMAT Entry Code: z	Files: (1) data in FILE FT03F001 Keyboard: (1) length of time series (2) format of time series	Files: (1) original data put in FORMAT(5F15.6) in FILE FT02F001 (2) original data unchanged in FILE FT03F001	(1) puts date into proper format for Time Series Editor (2) single precision
Name: CMSWORK Entry Code: C	no specific input; normal usage would include file name alteration, obtaining disc status, or erasing files no longer required	no specific output	(1) allows users to perform CMS admin actions while in TIMESER environment
Name: TRANS Entry Code: T	Files: (1) data in FILE FT02F001 Keyboard: (1) origin translation? (2) scale change factor? (3) log transform? (4) power/root transform?	Files: (1) original data unchanged in DATA FT02F001 (2) transformed data in FILE FT02F001 (3) transformation parameters in FILE FT07F001	(1) allows user to transform data in a file (2) single precision

PROGRAM	INPUT	OUTPUT	REMARKS
Name: DIFF Entry Code: D	Files: (1) original (transformed if desired) series in FILE FT02F001 Keyboard: (1) series seasonal? (2) number of non-seasonal differences (3) number of seasonal differences (4) length of seasonal period	Files: (1) original series unchanged in FILE FT02F001 (2) differenced series in FILE FT03F001	(1) allows user to perform differencing of a time series, in order to achieve series stationarity (2) uses IMSL subroutine FTRDIF (3) single precision
Name: PLOT Entry Code: P	Files: (1) original series in FILE FT02F001 Keyboard: (1) title for plot	Files: (1) original series unchanged in FILE FT02F001 Offline: (1) plot of time series	(1) allows user to plot any time series using offline printer (2) uses SSPLIB routine PLOT8 (3) single precision

PROGRAM	INPUT	OUTPUT	REMARKS
Name: AUTO Entry Code: A	Files: (1) original series in FILE FT02F001 transformed and/or differenced if desired Keyboard: (1) number of autos/pautos to be calculated (2) title for plots of autos/pautos	Files: (1) original series unchanged in FILE FT02F001 (2) plots of autos/pautos in FILE FT08F001 Terminal: (1) values of autos and pautos (2) mean (3) variance Offline: (1) plots of autos and pautos	(1) allows user to obtain basic statistics for time series (2) uses IMSL subroutine FTAUTO, as well as UTPLT8 routine (3) single precision
Name: ESTIMATE Entry Code: E	Files: (1) original series in FILE FT02F001; transformed and/or differenced as desired. Keyboard: (1) number of AR parameters (2) number of MA parameters (3) number of (non-seasonal) differences to be taken, if series not already differenced (4) titles for plots of residual autos and pautos	Files: (1) original series unchanged in FILE FT02F001 (2) model residuals in FILE FT02F001 Terminal: (1) estimated AR parameters (2) estimated MA parameters (3) MA constant (4) residual variance (5) portmanteau test of residuals Offline: (1) plots of residual autos and pautos	(1) allows user to obtain maximum likelihood parameter estimates for a general non-seasonal ARIMA model, as well as data concerning model sufficiency (2) uses IMSL subroutine FTMAXL (3) single precision

PROGRAM	INPUT	OUTPUT	REMARKS
Name: YESTSEAS Entry Code: Y	Files: (1) original series in FILE FT02F001 transformed if desired; and either differenced or undifferenced Keyboard: (1) number of seasonal and non-seasonal differences to be taken (2) length of seasonal period (3) numbers of both seasonal and non-seasonal AR and MA parameters	Files: (1) original series unchanged in FILE FT02F001 Terminal: (1) estimated values for requested seasonal and non-seasonal AR and MA parameters	(1) allows user to calculate initial non-seasonal and seasonal ARIMA model parameter estimates as input to WMARQRDT routine (2) uses IMSL subroutines FTRDIF, FTMAXL, FTAUTO, FTARPS and FTMAPS (3) single precision
Name: WMARQRDT Entry Code: W	Files: (1) original series in FILE FT02F001; may be transformed but not differenced (either diff or nondiff) Keyboard: (1) number of seasonal and non-seasonal differences to be taken (2) length of seasonal period	Files: (1) original series unchanged in FILE FT02F001 Terminal: (1) seasonal and non-seasonal AR and MA parameter estimates (2) parameter standard errors (3) MA constant term (4) sum of squared residuals (5) residual variance	(1) allows user to estimate non-linear least squares parameters for a general seasonal Box-Jenkins ARIMA model (2) requires initial parameter estimates, obtainable using YESTSEAS program (3) uses IMSL subroutines FTRDIF, FTAUTO, LINV1F, and MDCDFI, SSPLIB routine DPLOTP, and Time Series Editor resident subroutine PARSH, MARQRT, SUMSQ, SWAPB and FORMB

Name: WMARQRDT (CONTINUED)	(3) number and initial estimates of seasonal and non-seasonal AR and MA parameters	(6) residual variance (7) portmanteau test for model goodness-of-fit Offline: (1) plots of autos/pautos of residuals	(4) double precision (5) requires LOGIN with 450k core (6) if non-seasonal modeling, input length of season = 1
Name: XSUMSQ Entry Code: X	Files: (1) original series in FILE FT02F001; should be transformed and/or differenced as desired Keyboard: (1) number and estimates of seasonal and non-seasonal AR and MA parameters (2) length of seasonal period	Files: (1) original series unchanged in FILE FT02F001 Terminal: (1) value of residual sum of squares for the model and parameters specified	(1) allows user to obtain a residual sum of squares value for any seasonal or non-seasonal ARIMA model with specified parameters (2) uses Time Series Editor resident subroutine SUMSQ (3) double precision
Name: FORECAST Entry Code: F	Files: (1) original series in FILE FT02F001; transformed as desired, but not differenced Keyboard: (1) number of seasonal and non-seasonal differences to be taken	Files: (1) original series unchanged in FILE FT02F001 (2) forecast values and plot FILE FT08F001	(1) allows the user to forecast any seasonal or non-seasonal time series using a previously determined seasonal or non-seasonal ARIMA model and the time series itself

Name: FORECAST (CONTINUED)	(2) length of seasonal period (3) number and estimated values of seasonal and non-seasonal AR and MA parameters (4) MA constant (5) index for forecast origin (6) maximum forecast lead time (7) index for plot origin (8) confidence level for forecast confidence units	Offline: (1) plot of forecast of series, including listing of forecast values and confidence interval values	(2) uses IMSL subroutine FTRDlF and modified SSPLTB routine UTPLOT called UTPLT8 (3) single precision
Name: ROOTS Entry Code: R	Keyboard: (1) number of AR parameters in undifferenced form (2) values of AR parameters	Terminal: (1) values of roots	(1) allows user to calculate the roots of the characteristic equation for non-seasonal ARIMA models (2) uses IMSL routine ZPOLR (3) single precision
Name: HELP Entry Code: H	None	None	(1) allows user to access program information paragraphs after the TIMESER introduction phase has been completed

Name: GENERATE Entry Code: G	Keyboard: (1) random number seed (2) number and values for non-seasonal AR and MA ARIMA model parameters (3) MA constant term (4) residual variance (5) length of series to be generated (6) initial starting value for time series to be generated	Files: (1) generated time series written onto FILE FT02F001 Offline: (1) length of generated series and series values themselves are printed offline	(1) allows the user to generate a time series from a given non-seasonal ARIMA model, previously determined (2) uses IMSL subroutine FTGEN1 (3) single precision
Name: SIMULATE Entry Code: S	Files: (1) original series in FILE FT02F001, transformed and/or differenced as desired Keyboard: (1) number and values for non-seasonal AR and MA ARIMA model parameters (2) MA constant term (3) residual variance (4) index value of time series where simulation is to begin (5) starting values of series to be simulated (6) random number seed (7) number of values to be simulated in each series (8) number of series to be generated	Files: (1) original series unchanged in FILE FT02F001 Terminal: (1) Simulated series	(1) allows user to produce any number of simulated time series from a given non-seasonal ARIMA model (2) uses IMSL subroutine FTGEN1 (3) single precision

III. THE BASIC USER SESSION

To use the Time Series Editor, the user must log into CMS, get into CP, link to the disc storage area where the Time Series Editor resides, reimplement CMS, log into the general user and Time Series Editor disc areas, and enter the TIMESER routine. This section will provide explicit guidelines to enable the user to perform the above steps on the NPS CP/CMS system. Commands marked with an asterisk (*) are those actually entered on the terminal by the user (the asterisk itself is omitted). Those without an asterisk and those written in all capital letters are system responses at the terminal. Numbered sentences are comments, which will not appear during an actual user session. The instructions and system responses assure the user is on an IBM 2741 Input/Output Terminal. Some minor modifications may be necessary if other terminals are used.

1. Turn the terminal on, depress the BREAK key, and wait for the system to respond:

    CP-67 online xd.65 gsyosu

2. Depress the ATTN key. The roll bar will advance and the keyboard will unlock. Then enter:

    *login aaaapbb 450k

3. aaaa is the user's identification number, and nn is the terminal number (usually written on the terminal). For example, if the user's ID number is 1621 and the terminal number is 44, the input would be: login 1621p44 450k. The addition of 450 k to the normal login command is necessary to execute the program WMARQRDT in the Editor; for users not planning to execute this program during a session, this addition is not necessary.

4. The system will respond with the statement:

   ENTER PASSWORD:

5. The user then enters his password, or the general users password npg;

   *password

6. The system will then respond:

   ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:

7. The user then enters:

   *gggghhhh

8. gggg is the assigned project number, and hhhh is the user's section designator or the faculty code.

9. The system will respond with the message of the day, such as:

   CP/CMS HOURS ... 0930=2200(MON-THURS) ... 0930-1800(FRI)
   OUTPUT RETAINED 5 DAYS
   Cms Version 3.25

10. At this point, the user is in CMS. He must then get into CP; this can be done by hitting the ATTN key. The system will then respond:

    CP

11. The user must then link to the TIME SERIES EDITOR; this is accomplished by entering:

    *link 2069p 191 192

12. The system will respond with:

    ENTER PASSWORD:

13. The password (read only) to enter the Editor is:

    *timser

14. The system then responds:

    SET TO READ ONLY

15. The user now implements CMS by:

```
*ipl cms
```

16. The system will respond:

```
CMS Version 3.25
```

17. Now the user must log into both the general user and the Time Series Editor area by entering:

```
*login 191
```

18. The system will respond with a message such as:

```
R;
```

19. The user then enters the command:

```
*login 192 t,p
```

20. The system will respond:

```
T (192) R/O
R;
```

21. The user can then enter the Time Series Editor (guided version) by entering the command:

```
*timeser
```

22. The system will respond:

```
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY *

YOU HAVE ENTERED THE TIME SERIES EDITOR

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING
WITH I THROUGH N.  TYPE FLOATING VALUES WITH DECIMAL FOR
ALL OTHERS.

DO YOU WANT A LIST OF THE OPTIONS?
```

23. The user is then on his own, guided by the Exec routine. See the notes that appear at the end of this guide for additional information. Eventually the user will be asked:

```
DO YOU WANT TO TRY AGAIN?
```

24. If a yes response is given, another sequence will begin; if the response is no, the user will be taken out of the Time Series Editor environment and returned to CMS. The system response will be:

```
CONTROL RETURNED TO CMS
R;
```

25. The user can then log out of CMS by typing:

```
*cp logout
```

26. The system will respond with:

```
CONNECT= 00:08:02  VIRTCPU= 000:07.98  TOTCPU= 000.10.94
LOGOUT AT 14.22.04 on 10/16/78
```

27. The user should then turn off his terminal and tear off the output from his session.

The more experienced user can dispense with the "welcome aboard" section of the Time Series Editor and get right down to business by using the shortened version of the Editor. This shortened version may be entered by linking in the normal way, and then entering the Editor by typing the COMMAND

*timeser s   (asterisk omitted).

The system will immediately respond:

ENTER LETTER FOR OPTION YOU WANT.

The session inside the Editor then begins.

IV. BRIEF SAMPLE USER SESSION

A brief sample user session is given below; it includes copies of the offline output generated during the session.

```
repeat login  nur@pn@

login 1621p44 450k
ENTER PASSWORD:

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:
0444r172
READY AT 17.24.38 ON 09/16/78
CMS Version 3.25

stat
P (191): 29 FILES; 241 REC IN USE, 55 LEFT (of 296), 81% FULL (2 CYL)
R;
cp q f
FILES:- NO RDR, NO PRT, NO PUN
R;
CP
link 2069p 191 192
ENTER PASSWORD:

SET TO READ ONLY

ipl cms
CMS Version 3.25

login 191
R;
login 192 t,p
T (192) R/O
R;
timeser
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY *.

YOU HAVE ENTERED THE TIME SERIES EDITOR.

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING
WITH I THRU N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.

DO YOU WANT A LIST OF THE OPTIONS?
Y


OPTION                        DESCRIPTION
GENERATE -----GENERATE ANY ARIMA TIME SERIES
AUTO ---------CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT ---------PLOT A TIME SERIES
ESTIMATE -----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
DIFF ---------DIFFERENCE A TIME SERIES
FORECAST -----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
TRANS --------TRANSFORMS VALUES OF A TIME SERIES
ROOTS --------DETERMINES ROOTS OF ARIMA CHARACTERISTIC EQUATION
ZFORMAT ------ALTER DATA FILE TO FORMAT 5F15.6
CMSWORK ------PERFORM CP/CMS COMMANDS IN TIMESER EXEC
SIMULATE -----SIMULATE NONSEASONAL TIME SERIES
YESTSEAS -----CALCULATE INITIAL SEASONAL PARAMETERS
WMARQRDT -----MARQUARDT SOLUTION FOR PARAMETER ESTIMATES
XSUMSQ -------CALCULATE SUM OF SQUARES FOR ARBITRARY PARAMETERS


WOULD YOU LIKE MORE INFO?
Y
```

```
ENTER OPTION YOU WANT INFO ABOUT.
a

AUTO --------THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL
AUTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES
WHICH MUST RESIDE IN FILE FT02F001.  THE PROGRAM USES
FTAUTO IN THE IMSL LIBRARY.  THE AUTOCORRELATIONS AND PAUTOS CAN BE
PLOTTED OFFLINE.


DO YOU WANT INFO ABOUT ANOTHER OPTION?
n
DO YOU WANT TO TRY A SESSION?
y

ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
listf * ft02f001
FILENAME FILETYPE MODE NO.REC. DATE
SERG     FT02F001  P1      3    9/16
SERC     FT02F001  P1      5    9/16
LNSERG   FT02F001  P1      3    9/16
FILE     FT02F001  P1      1    9/16
erase file ft02f001
alter serc ft02f001 p1 file ft02f001 p1
stat
P (191): 28 FILES; 240 REC IN USE, 56 LEFT (of 296), 81% FULL (2 CYL)
&goto -ques
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
a
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

 0.978  0.944  0.902  0.854  0.802  0.748  0.692  0.635  0.579  0.523
 0.468  0.413  0.359  0.305  0.253  0.201  0.150  0.098  0.047 -0.003
-0.052 -0.101 -0.151 -0.200 -0.248


         PARTIAL AUTOCORRELATIONS

 0.978 -0.260 -0.157 -0.093 -0.058 -0.045 -0.012 -0.038 -0.022 -0.010
-0.036 -0.041 -0.038 -0.024 -0.037 -0.027 -0.032 -0.070 -0.048 -0.024
-0.034 -0.061 -0.079 -0.048 -0.037


    MEAN= 22.9739          VARIANCE =   4.22273

 ENTER TITLE FOR PLOTS.
autos and pautos for series c data
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
offline print file ft02f001
alter file ft02f001 p1 serc ft02f001 p1
&goto -ques
DO YOU WANT TO GO AGAIN?
n
CONTROL RETURNED TO CMS
R;
```

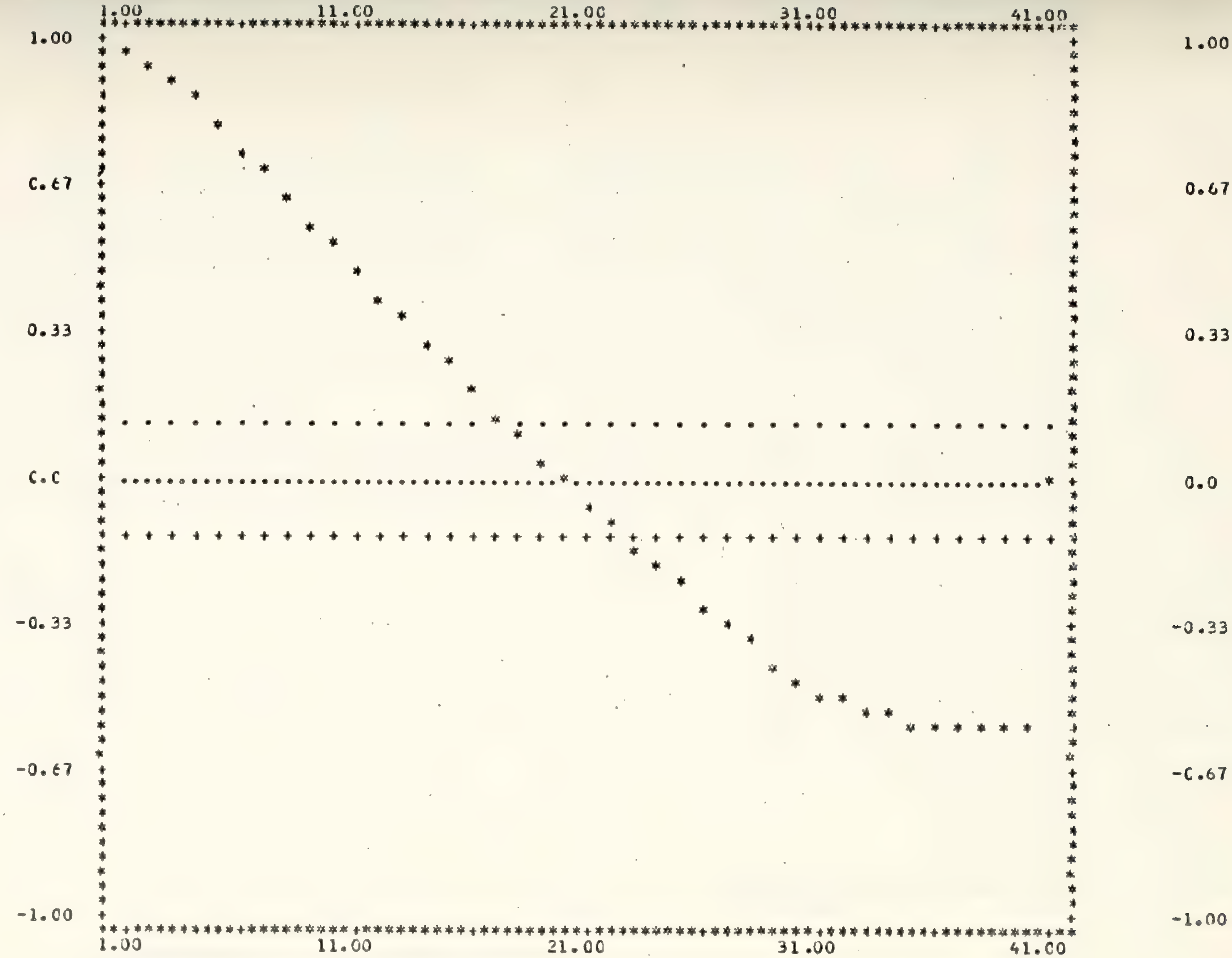
AUTOCORRELATIONS

0.978	0.944	0.902	0.854	0.802	0.748	0.692	0.635	0.579	0.523
0.466	0.413	0.359	0.305	0.253	0.201	0.150	0.098	0.047	-0.003
-0.052	-0.101	-0.151	-0.200	-0.248	-0.294	-0.337	-0.379	-0.418	-0.454
-0.486	-0.512	-0.534	-0.550	-0.562	-0.570	-0.573	-0.573	-0.568	-0.562

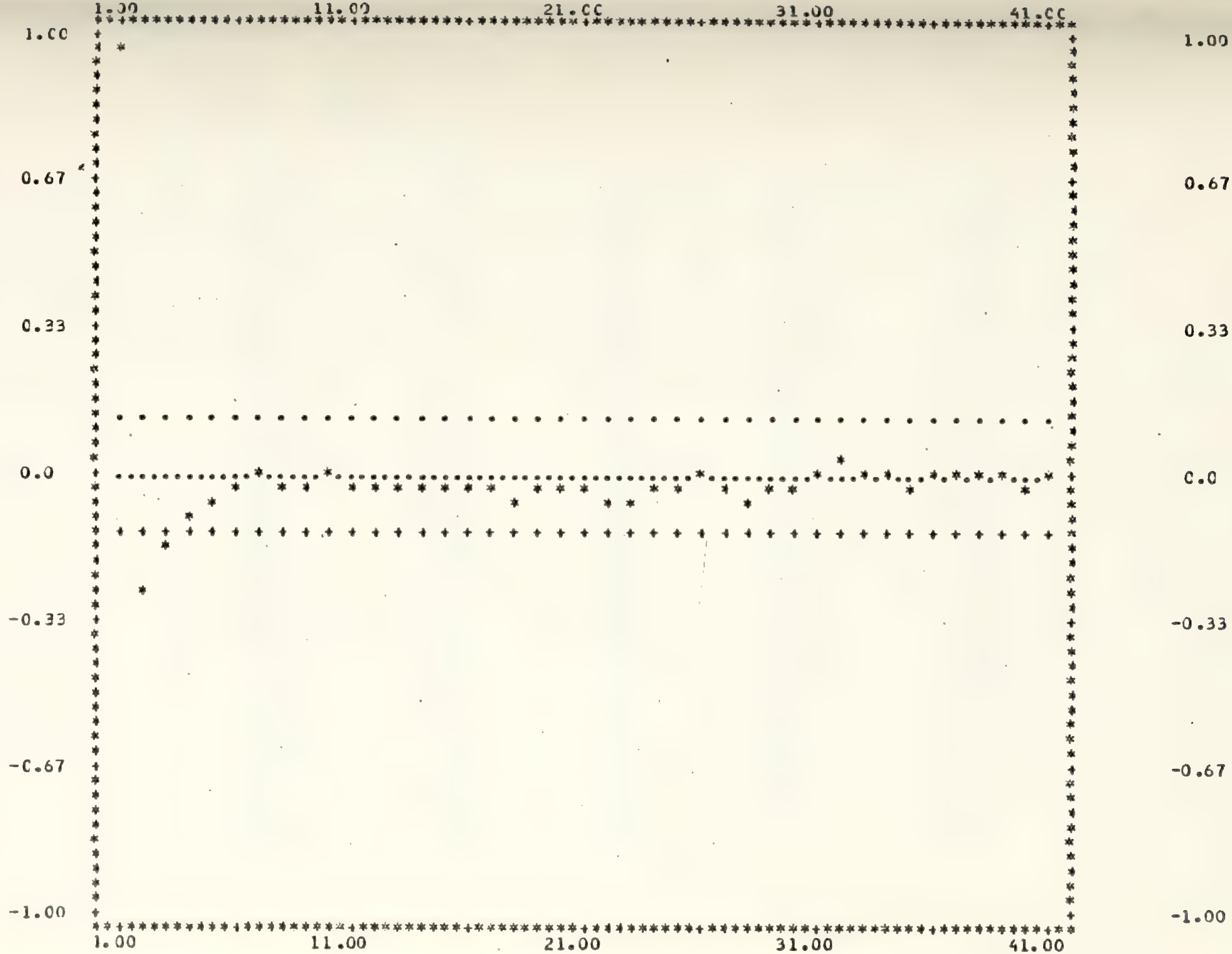
PARTIAL AUTOCORRELATIONS

0.978	-0.260	-0.157	-0.093	-0.058	-0.045	-0.012	-0.038	-0.022	-0.010
-0.036	-0.041	-0.038	-0.024	-0.037	-0.027	-0.032	-0.070	-0.048	-0.024
-0.034	-0.061	-0.079	-0.046	-0.037	-0.011	-0.031	-0.054	-0.036	-0.024
-0.002	0.022	-0.014	-0.006	-0.024	0.006	-0.016	-0.004	-0.010	-0.036

MEAN= 22.9739 VARIANCE = 4.22273



AUTCCCRRFLATICNS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
ALTOS AND PAUTOS FOR SERIES C DATA

C9/16/78 17.46.29

FILE: SERC FT02F001 P1 N P S

226

26.6	27.0	27.1	27.1	27.1
27.1	26.9	26.8	26.7	26.4
26.0	25.8	25.6	25.2	25.0
24.6	24.2	24.0	23.7	23.4
23.1	22.9	22.8	22.7	22.6
22.4	22.2	22.0	21.8	21.4
20.9	20.3	19.7	19.4	19.3
19.2	19.1	19.0	18.9	18.9
19.2	19.3	19.3	19.4	19.5
19.6	19.6	19.6	19.6	19.6
19.7	19.9	20.0	20.1	20.2
20.3	20.6	21.6	21.9	21.7
21.3	21.2	21.4	21.7	22.2
23.0	23.8	24.6	25.1	25.6
25.8	26.1	26.3	26.3	26.2
26.0	25.8	25.6	25.4	25.2
24.9	24.7	24.5	24.4	24.4
24.4	24.4	24.4	24.3	24.4
24.4	24.4	24.4	24.4	24.5
24.5	24.4	24.3	24.2	24.2
24.0	23.9	23.7	23.6	23.5
23.5	23.5	23.5	23.5	23.7
23.8	23.8	23.9	23.9	23.8
23.7	23.6	23.4	23.2	23.0
22.8	22.6	22.4	22.0	21.6
21.3	21.2	21.2	21.1	21.0
20.9	21.0	21.0	21.1	21.2
21.1	20.9	20.8	20.8	20.8
20.8	20.9	20.8	20.8	20.7
20.7	20.8	20.9	21.2	21.4
21.7	21.8	21.9	22.2	22.9
22.8	23.1	23.4	23.8	24.1
24.6	24.9	24.9	25.1	25.0
25.0	25.0	25.0	24.9	24.8
24.7	24.6	24.5	24.5	24.5
24.5	24.5	24.5	24.5	24.4
24.4	24.2	24.2	24.1	24.1
24.0	24.0	24.0	23.9	23.8
23.8	23.7	23.7	23.6	23.7
23.6	23.6	23.6	23.5	23.5
23.4	23.3	23.3	23.3	23.4
23.4	23.3	23.2	23.3	23.3
23.2	23.1	22.9	22.8	22.6
22.4	22.2	21.8	21.3	20.8
20.2	19.7	19.3	19.1	19.0
18.8				

V. PROBLEM CONTROL NOTES

This section will cover corrective measures that can be taken when things fail to go as expected while in the TIMESER environment.

a. A typing error in the CMS environment can be corrected by typing the @ character as many times as is required to back up and then type the correct values. For example, if the user typed timesre, the user could correct the mistake by typing two @ signs, followed by the correct spelling er, as follows: timesre@@re. An entire line can be deleted by typing the ¢ character (or [on some terminals).

b. When working with TIMESER executive programs, the user should exercise care before hitting the return key (or control s on some terminals). If an input value is required and the return key is hit before the proper response is entered, the user will be likely to get thrown out of the editor and have to begin again. In most cases, errors can be corrected only before the return key is struck (in some programs you get a second chance for input).

c. Particular care should be taken for integer value input, which must be right justified in the format field. The editor will advise the user in all cases where the integer format is other than I1.

d. If for any reason the user finds himself in a debug or error condition (caused by erroneous data, or a "blowup" in one of the non-linear optimization routines usually

caused by very poor initial input values), the following procedure will get the user back into the normal TIMESER environment:

(1) depress the ATTN key twice; this gets the user into CP; hit the ATTN key again, and then type kx to kill the execution.
(2) re-ipl CMS, and login 191 and then login 192 t,p.
(3) then the user can type TIMESER or TIMESER S, and return to the TIMESER environment

On the next page is a sample user session where an error causing a debug condition has occurred.

Here the user executed a program that required data in FILE FT02F001, and the FILE did not exist. As the example shows, recovery is quick. Simply hit the break button to get into CP, login 191, login 192 t,p, and then type timeser s to return immediately to the Editor environment.

```
ENTER LETTER FOR OPTION YOU WANT.
d
EXECUTION BEGINS...

IHC218I FIOCS - I/O ERROR  BSAM INPUT  ERROR 01 ON FILE: "FT02F001"  ,

   8

TRACEBACK  ROUTINE  CALLED FROM ISN   REG. 14   REG. 15   REG.  0   REG.  1

           IBCOM                      000131FC  000133F8  FFF93908  00014F80

           DIFF             CP
ipl cms
CMS Version 3.25

login 191
R;
login 192 t,p
T (192) R/O
R;

timeser s

ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
alter serc ft02f001 pl file ft02f001 pl
&goto -ques
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
d
```

APPENDIX B

KEYBOARD SESSION AND OUTPUT FROM ANALYSIS OF TIME SERIES C (NON-SEASONAL)

This appendix contains the complete terminal keyboard session and all offline output from the analysis of Box and Jenkins' [Ref. 4] time series C (Chemical process temperature readings) using the Time Series Editor. This appendix is intended to supplement the discussion of the analysis of series C discussed in Chapter V of this report.

The terminal listings are presented first, followed by the computer offline output.

```
repeat login  nur@pn@

login 1621p44 400k
ENTER PASSWORD:

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:
0444r172
READY AT 14.23.02 ON 09/16/78
CMS Version 3.25

listf * ft02f001
FILENAME FILETYPE MODE NO.REC. DATE
FILE     FT02F001  P1       3    9/15
SERG     FT02F001  P1       3    9/16
SERC     FT02F001  P1       5    9/16
R;

erase file ft02f001
R;
alter serc ft02f001 pl file ft02f001 pl
R;

CP
link 2069p 191 192
ENTER PASSWORD:

SET TO READ ONLY

ipl cms
CMS Version 3.25

login 191
R;
login 192 t,p
T (192) R/O
R;
    ser
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY *.

YOU HAVE ENTERED THE TIME SERIES EDITOR.

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING
WITH I THRU N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.

DO YOU WANT A LIST OF THE OPTIONS?
y

OPTION                      DESCRIPTION
GENERATE -----GENERATE ANY ARIMA TIME SERIES
AUTO ---------CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT ---------PLOT A TIME SERIES
ESTIMATE -----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
DIFF ---------DIFFERENCE A TIME SERIES
FORECAST -----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
TRANS --------TRANSFORMS VALUES OF A TIME SERIES
ROOTS --------DETERMINES ROOTS OF ARIMA CHARACTERISTIC EQUATION
ZFORMAT ------ALTER DATA FILE TO FORMAT 5F15.6
CMSWORK ------PERFORM CP/CMS COMMANDS IN TIMESER EXEC
SIMULATE -----SIMULATE NONSEASONAL TIME SERIES
YESTSEAS -----CALCULATE INITIAL SEASONAL PARAMETERS
WMARQRDT -----MARQUARDT SOLUTION FOR PARAMETER ESTIMATES
XSUMSQ -------CALCULATE SUM OF SQUARES FOR ARBITRARY PARAMETERS


WOULD YOU LIKE MORE INFO?
y
```

```
ENTER OPTION YOU WANT INFO ABOUT.
a

AUTO --------THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL
AUTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES
WHICH MUST RESIDE IN FILE FT02F001.  THE PROGRAM USES
FTAUTO IN THE IMSL LIBRARY.  THE AUTOCORRELATIONS AND PAUTOS CAN BE
PLOTTED OFFLINE.


DO YOU WANT INFO ABOUT ANOTHER OPTION?
y
ENTER OPTION YOU WANT INFO ABOUT.
d

DIFF --------THIS PROGRAM TAKES A SERIES IN FILE FT02F001, ASKS IF
IT IS SEASONAL, AND THEN PERFORMS NONSEASONAL AND/OR SEASONAL
DIFFERENCING, AS REQUESTED.  THE ORIGINAL DATA REMAINS IN FILE
FT02F001, WHILE THE DIFFERENCED SERIES IS PUT IN FILE FT03F001.


DO YOU WANT INFO ABOUT ANOTHER OPTION?
n
DO YOU WANT TO TRY A SESSION?
y

ENTER LETTER FOR OPTION YOU WANT.
a
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

 0.978  0.944  0.902  0.854  0.802  0.748  0.692  0.635  0.579  0.523
 0.468  0.413  0.359  0.305  0.253  0.201  0.150  0.098  0.047 -0.003
-0.052 -0.101 -0.151 -0.200 -0.248


         PARTIAL AUTOCORRELATIONS

 0.978 -0.260 -0.157 -0.093 -0.058 -0.045 -0.012 -0.038 -0.022 -0.010
-0.036 -0.041 -0.038 -0.024 -0.037 -0.027 -0.032 -0.070 -0.048 -0.024
-0.034 -0.061 -0.079 -0.048 -0.037


    MEAN= 22.9739          VARIANCE =  4.22273

 ENTER TITLE FOR PLOTS.
autos and pautos of series c data / undifferenced
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
*DO YOU WANT TO GO AGAIN?
y
```

```
ENTER LETTER FOR OPTION YOU WANT.
d
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 IS YOUR TIME SERIES SEASONAL?
n
 ENTER NUMBER OF NONSEASONAL DIFFERENCES.
1
*DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

 0.805  0.653  0.526  0.442  0.380  0.318  0.262  0.186  0.139  0.144
 0.097  0.094  0.074  0.073  0.070  0.072  0.089  0.048  0.041  0.040
 0.044  0.048  0.000 -0.052 -0.097


          PARTIAL AUTOCORRELATIONS

 0.805  0.010 -0.007  0.051  0.027 -0.019 -0.013 -0.080  0.020  0.117
-0.137  0.094 -0.027  0.034  0.006  0.012  0.043 -0.121  0.060 -0.005
 0.038 -0.022 -0.116 -0.076 -0.008


    MEAN=-.346667E-01     VARIANCE = 0.531982E-01

 ENTER TITLE FOR PLOTS.
autos and pautos of series c data / one nonseasonal difference
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
d
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 IS YOUR TIME SERIES SEASONAL?
n
 ENTER NUMBER OF NONSEASONAL DIFFERENCES.
2
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

-0.079 -0.065 -0.122 -0.063  0.013 -0.018  0.049 -0.052 -0.124  0.122
-0.122  0.072 -0.077  0.029 -0.011 -0.058  0.171 -0.101 -0.013 -0.020
-0.007  0.135  0.014 -0.013 -0.135


          PARTIAL AUTOCORRELATIONS

-0.079 -0.072 -0.135 -0.094 -0.022 -0.051  0.022 -0.060 -0.145  0.094
-0.143  0.023 -0.089 -0.005 -0.039 -0.074  0.130 -0.105 -0.014 -0.053
 0.004  0.081  0.056 -0.041 -0.099


    MEAN=-.267866E-02     VARIANCE = 0.198143E-01

 ENTER TITLE FOR PLOTS.
autos and pautos of series c data / two nonseasonal differences
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
```

```
DO YOU WANT TO GO AGAIN?
y
*
ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
alter file ft02f001 pl serc ft02f001 pl
alter file ft03f001 pl file ft02f001 pl
&goto -ques

DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
e
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 ENTER NUMBER OF AR PARAMETERS (EXCLUDE DIFFERENCES).
0
 ENTER NUMBER OF MA PARAMETERS.
2
 LENGTH OF TIME SERIES = 224
 0 AR PARAMETERS     2 MA PARAMETERS

 MA PARAMETERS ARE:
 THETA(1)=   0.1378

 THETA(2)=   0.1296

 MA CONSTANT=  -0.26787E-02      WHITE NOISE VARIANCE=     0.189559E-01

 CHI SQUARE RESIDUAL LACK OF FIT VALUE =  36.75    DF = 23
         SIGNIFICANCE = 0.0346
DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
y
*EXECUTION BEGINS...
               AUTOCORRELATIONS

 0.019  0.034 -0.134 -0.093 -0.012 -0.043  0.005 -0.063 -0.125  0.088
-0.142  0.069 -0.098  0.025  0.004 -0.055  0.157 -0.090  0.005 -0.006
 0.009  0.133  0.005 -0.015 -0.133


          PARTIAL AUTOCORRELATIONS

 0.019  0.033 -0.135 -0.090  0.001 -0.055 -0.019 -0.071 -0.143  0.087
-0.166  0.017 -0.104 -0.013 -0.025 -0.089  0.123 -0.123 -0.021 -0.025
 0.024  0.069  0.024 -0.069 -0.102


    MEAN=0.236684E-02       VARIANCE = 0.189503E-01

 ENTER TITLE FOR PLOTS.
autos and pautos of residuals / arima(0,2,2) model of series c data
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?
y
```

```
ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
erase file ft02f001
stat
P (191): 27 FILES; 265 REC IN USE, 31 LEFT (of 296), 90% FULL (2 CYL)
erase file ft08f001
alter serc ft02f001 pl file ft02f001 pl
&goto -ques
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
d
*IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 IS YOUR TIME SERIES SEASONAL?
n
 ENTER NUMBER OF NONSEASONAL DIFFERENCES.
1
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
n
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
c
*ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
alter file ft02f001 pl serc ft02f001 pl
alter file ft03f001 pl file ft02f001 pl
&goto -ques
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
e

IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 ENTER NUMBER OF AR PARAMETERS (EXCLUDE DIFFERENCES).
1
 ENTER NUMBER OF MA PARAMETERS.
0
* LENGTH OF TIME SERIES = 225
 1 AR PARAMETERS     0 MA PARAMETERS

 AR PARAMETERS ARE:
 PHI(1)=   0.8073

 MA CONSTANT=  -0.66789E-02     WHITE NOISE VARIANCE=    0.177633E-01

 CHI SQUARE RESIDUAL LACK OF FIT VALUE =  28.88    DF = 24
        SIGNIFICANCE = 0.2247
DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

 0.016  0.014 -0.049 -0.005  0.061  0.024  0.078 -0.018 -0.087  0.130
-0.093  0.084 -0.055  0.043  0.007 -0.040  0.169 -0.079 -0.001 -0.010
 0.000  0.129  0.014 -0.013 -0.127
```

```
          PARTIAL AUTOCORRELATIONS

  0.016  0.014 -0.050 -0.004  0.063  0.019  0.075 -0.015 -0.087  0.14?
 -0.104  0.070 -0.048  0.042  0.003 -0.030  0.158 -0.088  0.013 -0.025
  0.030  0.086  0.039 -0.062 -0.101


     MEAN=-.252517E-02      VARIANCE = 0.177569E-01

  ENTER TITLE FOR PLOTS.
 autos and pautos of residuals / arima(1,1,0) model of series c data
  YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
  PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

 DO YOU WANT TO GO AGAIN?
 y
 *
 ENTER LETTER FOR OPTION YOU WANT.
 c

 ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
 WHEN FINISHED TYPE: &GOTO -QUES
 erase file ft02f001
 alter serc ft02f001 p1 file ft02f001 p1
 &goto -ques
 DO YOU WANT TO GO AGAIN?
 y

 ENTER LETTER FOR OPTION YOU WANT.
 f
 IS YOUR DATA IN FILE FT02F001?
 y
 EXECUTION BEGINS...

  IS YOUR SERIES SEASONAL?
 n

  ENTER NONSEASONAL DATA AS REQUESTED:

  ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
 1
  ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
 1
  ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
 0

  NOW INPUT YOUR PARAMETER ESTIMATES:


  ENTER MA CONSTANT TERM, THETA0.
 -.00667
  ENTER NON-SEASONAL AR PARAMETER PHI(1).
 0.8073
  ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.
 25
  ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.
 200
  ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.
 220
  ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.
 0.10

  WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?
 n

  DO YOU WANT BASIC OUTPUT AT THE TERMINAL?
 y
```

```
 THE LAST 10 WVEC VALUES:

 0.222000E 02  0.218000E 02  0.213000E 02  0.208000E 02  0.202000E 02
 0.197000E 02  0.193000E 02  0.191000E 02  0.190000E 02  0.188000E 02

 THE 25 FORECAST VALUES:

 0.203896E 02  0.200517E 02  0.197722E 02  0.195399E 02  0.193456E 02
 0.191821E 02  0.190434E 02  0.189248E 02  0.188223E 02  0.187329E 02
 0.186541E 02  0.185837E 02  0.185203E 02  0.184623E 02  0.184089E 02
 0.183591E 02  0.183121E 02  0.182676E 02  0.182249E 02  0.181838E 02
 0.181439E 02  0.181050E 02  0.180669E 02  0.180295E 02  0.179926E 02

 THE 25 UPPER FORECAST CONFIDENCE LIMITS:

 0.206094E 02  0.205056E 02  0.204779E 02  0.205033E 02  0.205662E 02
 0.206551E 02  0.207621E 02  0.208812E 02  0.210079E 02  0.211390E 02
 0.212721E 02  0.214056E 02  0.215381E 02  0.216687E 02  0.217969E 02
 0.219221E 02  0.220442E 02  0.221630E 02  0.222783E 02  0.223903E 02
 0.224989E 02  0.226043E 02  0.227064E 02  0.228055E 02  0.229016E 02

 ALPHA FOR THE CONFIDENCE LIMITS IS: 0.100

DO YOU WANT TO GO AGAIN?
y
ENTER LETTER FOR OPTION YOU WANT.
r
EXECUTION BEGINS...
 SOLVES FOR ROOTS OF CHARACTERISTIC EQUATION.

 ENTER NO. OF AR PARAMETERS (UNDIFF. FORM).
2
   ENTER AUTOREGRESSIVE PARAMETERS:
 ENTER PHI(1).
1.8073
 ENTER PHI(2).
-0.8073

  THE 2 ROOTS OF CHARACTERISTIC EQ. AND NORMS ARE:
       1.239      0.0        1.239
       1.000      0.0        1.000

DO YOU WANT TO GO AGAIN?
y


ENTER LETTER FOR OPTION YOU WANT.
d
*EXECUTION BEGINS...
 IS YOUR TIME SERIES SEASONAL?
n
 ENTER NUMBER OF NONSEASONAL DIFFERENCES.
0
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
n
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
s
*EXECUTION BEGINS...
 ENTER NUMBER OF AR PARAMETERS (UNDIFFERENCED FORM)
2
 ENTER ESTIMATED AR PARAMETER PHI(1).
1.8073
 ENTER ESTIMATED AR PARAMETER PHI(2).
-0.8073
```

```
 AR PARAMETERS ARE        1.8073        -0.8073
 ARE THESE OK?
y
 ENTER  NUMBER OF MA PARAMETERS
0
 ENTER OVERALL MA CONSTANT
-0.00667
 ENTER ESTIMATED WHITE NOISE VAR
0.0177
 DO YOU WANT STARTING VALUES TO BE THE LAST VALUES
  OF THE ACTUAL SERIES?
y
 START(1)=      19.000000
 START(2)=      18.799988
 STARTING VALUE(S) OK?
y
 ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).
0.12345
 ENTER NUMBER OF VALUES YOU WANT TO SIMULATE VIA I3.
 50
 DO YOU WANT A PRINTOUT OF THE FIRST 20 VALUES?
y
 SIMULATED VALUES ARE:
      18.50224       18.33957       18.33694       18.16435       17.98804
      17.85420       17.69398       17.58267       17.50722       17.26422
      16.94655       16.68689       16.43227       16.42499       16.26595
      16.31497       16.64629       17.04015       17.47137       17.62828

DO YOU WANT TO GO AGAIN?
n
CONTROL RETURNED TO CMS
R;
```

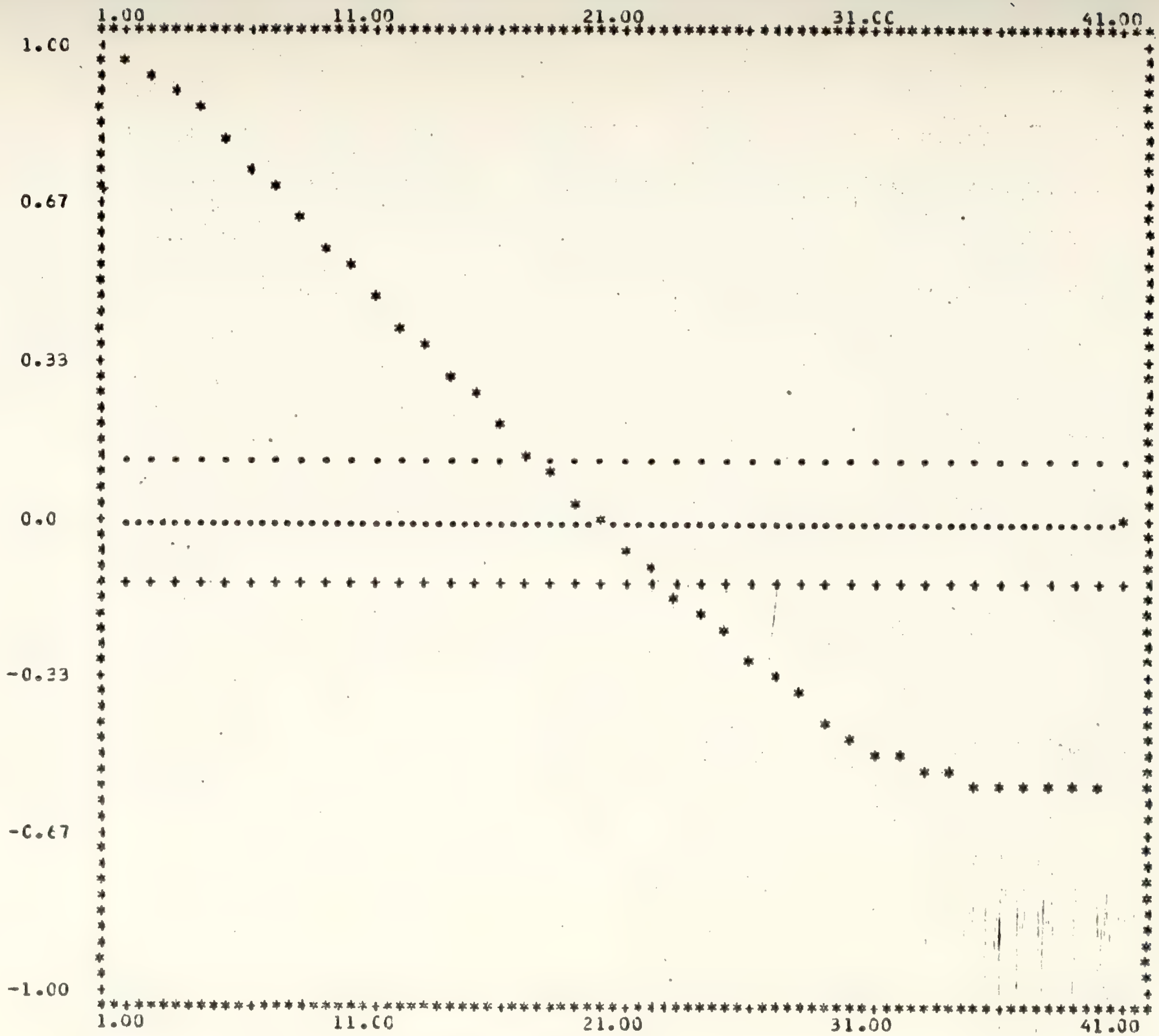
AUTOCORRELATIONS

0.978	0.944	0.902	0.854	0.802	0.748	0.692	0.635	0.579	0.523
0.468	0.413	0.359	0.305	0.253	0.201	0.150	0.098	0.047	-0.003
-0.052	-0.101	-0.151	-0.200	-0.248	-0.294	-0.337	-0.379	-0.418	-0.454
-0.486	-0.512	-0.534	-0.550	-0.562	-0.570	-0.573	-0.573	-0.568	-0.562

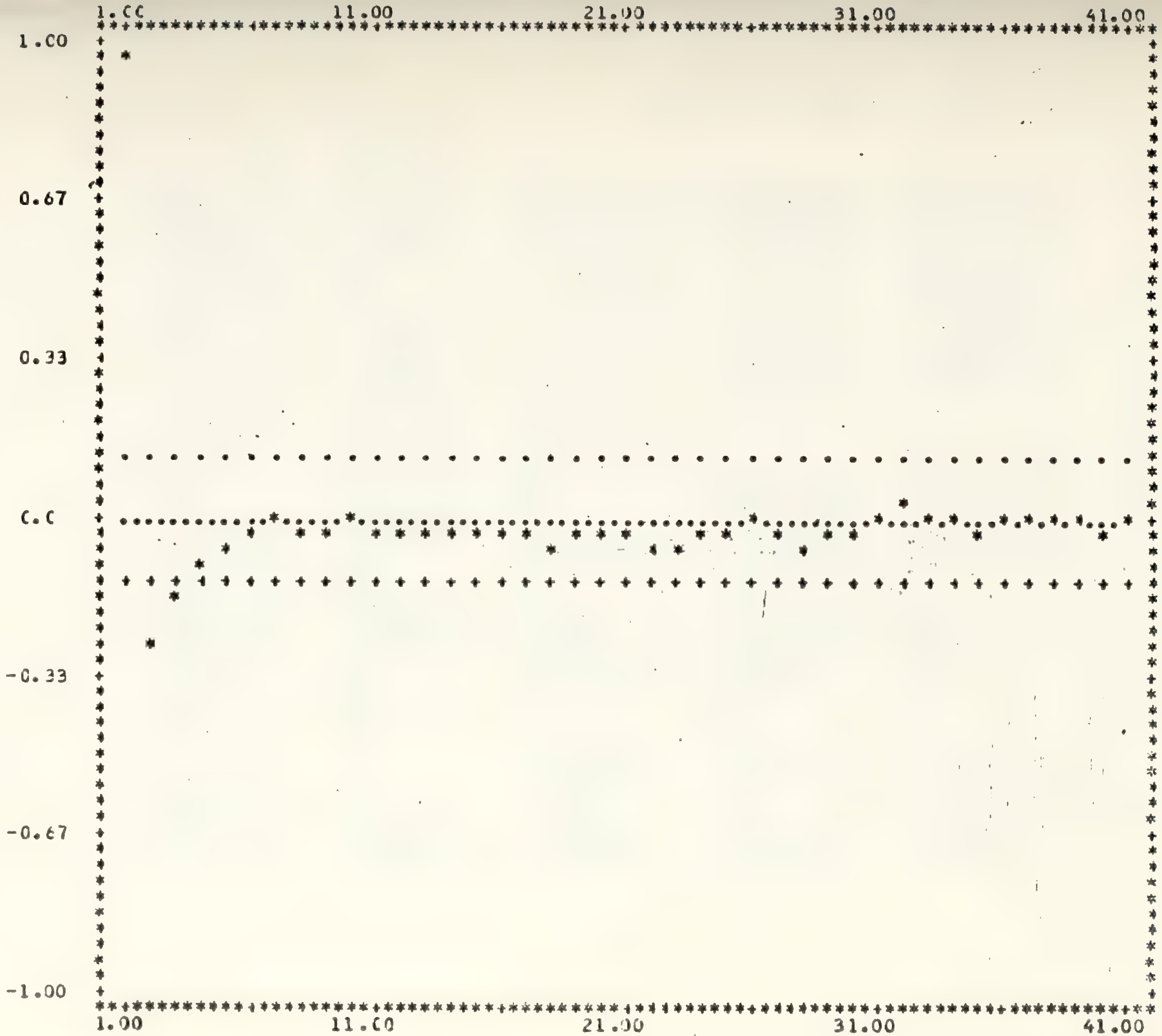
PARTIAL AUTOCORRELATIONS

0.978	-0.260	-0.157	-0.093	-0.058	-0.045	-0.012	-0.038	-0.022	-0.010
-0.036	-0.041	-0.038	-0.024	-0.037	-0.027	-0.032	-0.070	-0.048	-0.024
-0.034	-0.061	-0.079	-0.048	-0.037	-0.011	-0.031	-0.054	-0.036	-0.024
-0.002	0.022	-0.014	-0.006	-0.024	0.006	-0.016	-0.004	-0.010	-0.036

MEAN= 22.9739 VARIANCE = 4.22273



AUTOCORRELATICNS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
ALTOS AND PAUTOS OF SERIES C DATA / UNDIFFERENCED

22 5

0.400009E 00	0.999908E-01	0.0	0.0	0.0
-0.199997E 00	-0.100006E 00	-0.999908E-01	-0.300003E 00	-0.399994E 00
-0.200012E 00	-0.199997E 00	-0.399994E 00	-0.199997E 00	-0.400009E 00
-0.399994E 00	-0.199997E 00	-0.300003E 00	-0.300003E 00	-0.300003E 00
-0.199997E 00	-0.100006E 00	-0.999908E-01	-0.100006E 00	-0.199997E 00
-0.199997E 00	-0.199997E 00	-0.200012E 00	-0.399994E 00	-0.500000E 00
-0.600006E 00	-0.599991E 00	-0.300003E 00	-0.100006E 00	-0.999908E-01
-0.100006E 00	-0.999908E-01	-0.100006E 00	0.0	0.300003E 00
0.999908E-01	0.0	0.100006E 00	0.100006E 00	0.999908E-01
0.0	0.0	0.0	0.0	0.100006E 00
0.199997E 00	0.100006E 00	0.999908E-01	0.100006E 00	0.999908E-01
0.300003E 00	0.100000E 01	0.300003E 00	-0.199997E 00	-0.400009E 00
-0.999908E-01	0.199997E 00	0.300003E 00	0.500000E 00	0.800003E 00
0.799988E 00	0.800003E 00	0.500000E 00	0.500000E 00	0.199997E 00
0.300003E 00	0.199997E 00	0.0	-0.999908E-01	-0.199997E 00
-0.200012E 00	-0.199997E 00	-0.199997E 00	-0.199997E 00	-0.300003E 00
-0.199997E 00	-0.199997E 00	-0.100006E 00	0.0	0.0
0.0	0.0	-0.100006E 00	0.100006E 00	0.0
0.0	0.0	0.0	0.100006E 00	0.0
-0.100006E 00	-0.100006E 00	-0.999908E-01	0.0	-0.199997E 00
-0.100006E 00	-0.199997E 00	-0.100006E 00	-0.999908E-01	0.0
0.0	0.0	0.0	0.199997E 00	0.999908E-01
0.0	0.100006E 00	0.0	-0.100006E 00	-0.999908E-01
-0.100006E 00	-0.199997E 00	-0.199997E 00	-0.199997E 00	-0.200012E 00
-0.199997E 00	-0.199997E 00	-0.399994E 00	-0.400009E 00	-0.300003E 00
-0.999908E-01	0.0	-0.100006E 00	-0.999908E-01	-0.100006E 00
0.100006E 00	0.0	0.999908E-01	0.100006E 00	-0.100006E 00
-0.199997E 00	-0.100006E 00	0.0	0.0	0.0
0.100006E 00	-0.100006E 00	0.0	-0.999908E-01	0.0
0.999908E-01	0.100006E 00	0.300003E 00	0.199997E 00	0.300003E 00
0.999908E-01	0.100006E 00	0.300003E 00	0.300003E 00	0.299988E 00
0.300003E 00	0.300003E 00	0.399994E 00	0.300003E 00	0.500000E 00
0.300003E 00	0.0	0.199997E 00	-0.999908E-01	0.0
0.0	0.0	-0.100006E 00	-0.100006E 00	-0.999908E-01
-0.100006E 00	-0.999908E-01	0.0	0.0	0.0
0.0	0.0	0.0	-0.100006E 00	0.0
-0.199997E 00	0.0	-0.100006E 00	0.0	-0.999908E-01
0.0	0.0	-0.100006E 00	-0.100006E 00	0.0
-0.999908E-01	0.0	-0.100006E 00	0.100006E 00	-0.100006E 00
0.0	0.0	-0.999908E-01	0.0	-0.100006E 00
-0.100006E 00	0.0	0.0	0.100006E 00	0.0
-0.100006E 00	-0.999908E-01	0.999908E-01	0.0	-0.999908E-01
-0.100006E 00	-0.199997E 00	-0.100006E 00	-0.199997E 00	-0.199997E 00
-0.199997E 00	-0.400009E 00	-0.500000E 00	-0.500000E 00	-0.599991E 00
-0.500000E 00	-0.400009E 00	-0.199997E 00	-0.999908E-01	-0.200012E 00

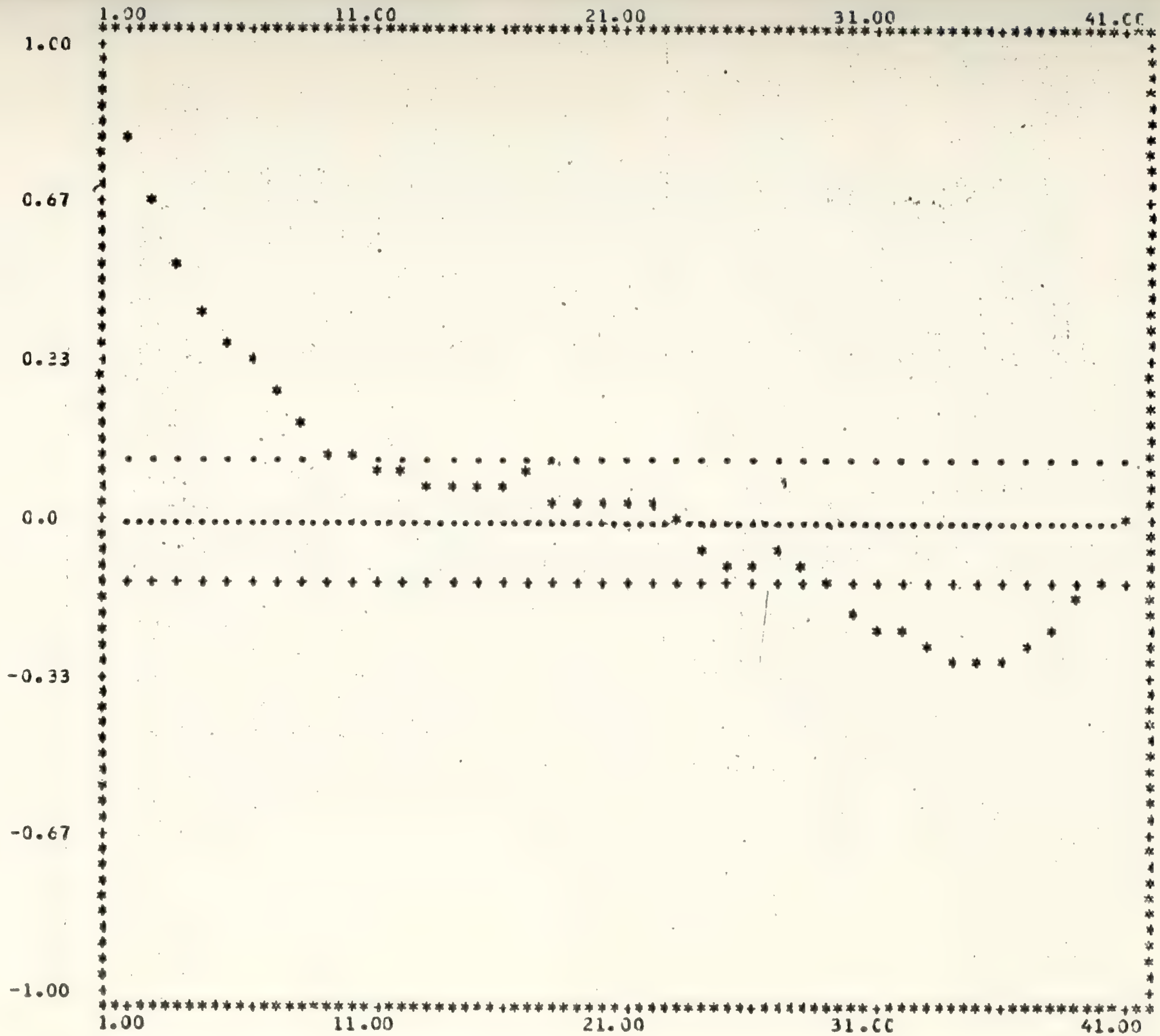
AUTOCORRELATIONS

0.805	0.653	0.526	0.442	0.380	0.318	0.262	0.186	0.139	0.144
0.097	0.054	0.074	0.073	0.070	0.072	0.089	0.048	0.041	0.040
0.044	0.048	0.000	-0.052	-0.097	-0.092	-0.083	-0.058	-0.119	-0.184
-0.226	-0.223	-0.261	-0.285	-0.313	-0.284	-0.258	-0.219	-0.166	-0.134

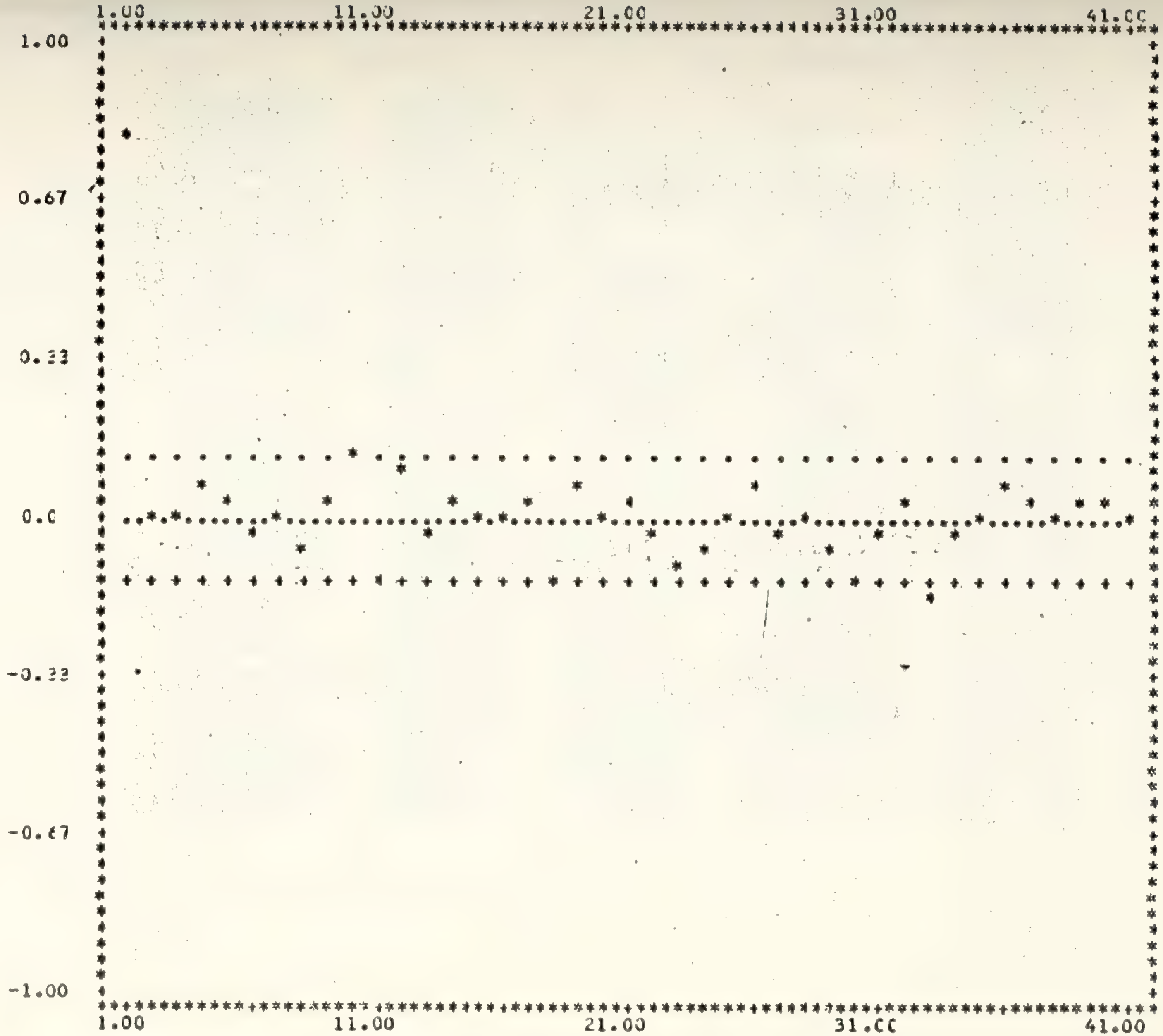
PARTIAL AUTOCORRELATIONS

0.805	0.010	-0.007	0.051	0.027	-0.019	-0.013	-0.080	0.020	0.117
-0.137	0.094	-0.027	0.034	0.006	0.012	0.043	-0.121	0.060	-0.005
0.038	-0.022	-0.116	-0.076	-0.008	0.071	-0.035	-0.015	-0.070	-0.125
-0.040	0.044	-0.154	-0.036	-0.013	0.065	0.019	0.016	0.048	0.043

MEAN=-.346667E-01 VARIANCE = 0.531982E-01



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTOS AND PAUTOS OF SERIES C DATA / ONE NONSEASONAL DIFFEREN

224

-0.200018E 00	-0.999908E-01	0.0	0.0	-0.199997E 00
0.999908E-01	0.152588E-04	-0.200012E 00	-0.999908E-01	0.199982E 00
0.152588E-04	-0.199997E 00	0.199997E 00	-0.200012E 00	0.152588E-04
0.199997E 00	-0.100006E 00	0.0	0.0	0.100006E 00
0.999908E-01	0.152588E-04	-0.152588E-04	-0.999908E-01	0.0
0.0	-0.152588E-04	-0.199982E 00	-0.100006E 00	-0.100006E 00
0.152588E-04	0.299988E 00	0.199997E 00	0.152588E-04	-0.152588E-04
0.152588E-04	-0.152588E-04	0.100006E 00	0.300003E 00	-0.200012E 00
-0.999908E-01	0.100006E 00	0.0	-0.152588E-04	-0.999918E-01
0.0	0.0	0.0	0.100006E 00	0.999908E-01
-0.999908E-01	-0.152588E-04	0.152588E-04	-0.152588E-04	0.200012E 00
0.699997E 00	-0.699997E 00	-0.500000E 00	-0.200012E 00	0.300018E 00
0.299988E 00	0.100006E 00	0.199997E 00	0.300003E 00	-0.152588E-04
0.152588E-04	-0.300003E 00	0.0	-0.300003E 00	0.100006E 00
-0.100006E 00	-0.199997E 00	-0.999908E-01	-0.100006E 00	-0.152588E-04
0.152588E-04	0.0	0.0	-0.100006E 00	0.100006E 00
0.0	0.999908E-01	0.100006E 00	0.0	0.0
0.0	-0.100006E 00	0.200012E 00	-0.100006E 00	0.0
0.0	0.0	0.100006E 00	-0.100006E 00	-0.100006E 00
0.0	0.152588E-04	0.999908E-01	-0.199997E 00	0.999908E-01
-0.999908E-01	0.999908E-01	0.152588E-04	0.999908E-01	0.0
0.0	0.0	0.199997E 00	-0.100006E 00	-0.999908E-01
0.100006E 00	-0.100006E 00	-0.100006E 00	0.152588E-04	-0.152588E-04
-0.999908E-01	0.0	0.0	-0.152588E-04	0.152588E-04
0.0	-0.199997E 00	-0.152588E-04	0.100006E 00	0.200012E 00
0.999908E-01	-0.100006E 00	0.152588E-04	-0.152588E-04	0.200012E 00
-0.100006E 00	0.999908E-01	0.152588E-04	-0.200012E 00	-0.999908E-01
0.999908E-01	0.100006E 00	0.0	0.0	0.100006E 00
-0.200012E 00	0.100006E 00	-0.999908E-01	0.999908E-01	0.999908E-01
0.152588E-04	0.199997E 00	-0.100006E 00	0.100006E 00	-0.200012E 00
0.152588E-04	0.199997E 00	0.0	-0.152588E-04	0.152588E-04
0.0	0.999908E-01	-0.999908E-01	0.199997E 00	-0.199997E 00
-0.300003E 00	0.199997E 00	-0.299988E 00	0.999908E-01	0.0
0.0	-0.100006E 00	0.0	0.152588E-04	-0.152588E-04
0.152588E-04	0.999908E-01	0.0	0.0	0.0
0.0	0.0	-0.100006E 00	0.100006E 00	-0.199997E 00
0.199997E 00	-0.100006E 00	0.100006E 00	-0.999908E-01	0.999908E-01
0.0	-0.100006E 00	0.0	0.100006E 00	-0.999908E-01
0.999908E-01	-0.100006E 00	0.200012E 00	-0.200012E 00	0.100006E 00
0.0	-0.999908E-01	0.999908E-01	-0.100006E 00	0.0
0.100006E 00	0.0	0.100006E 00	-0.100006E 00	-0.100006E 00
0.152588E-04	0.199982E 00	-0.999908E-01	-0.999908E-01	-0.152588E-04
-0.999908E-01	0.999908E-01	-0.999908E-01	0.0	0.0
-0.200012E 00	-0.999908E-01	0.0	-0.999908E-01	0.999908E-01
0.999908E-01	0.200012E 00	0.100006E 00	-0.100021E 00	

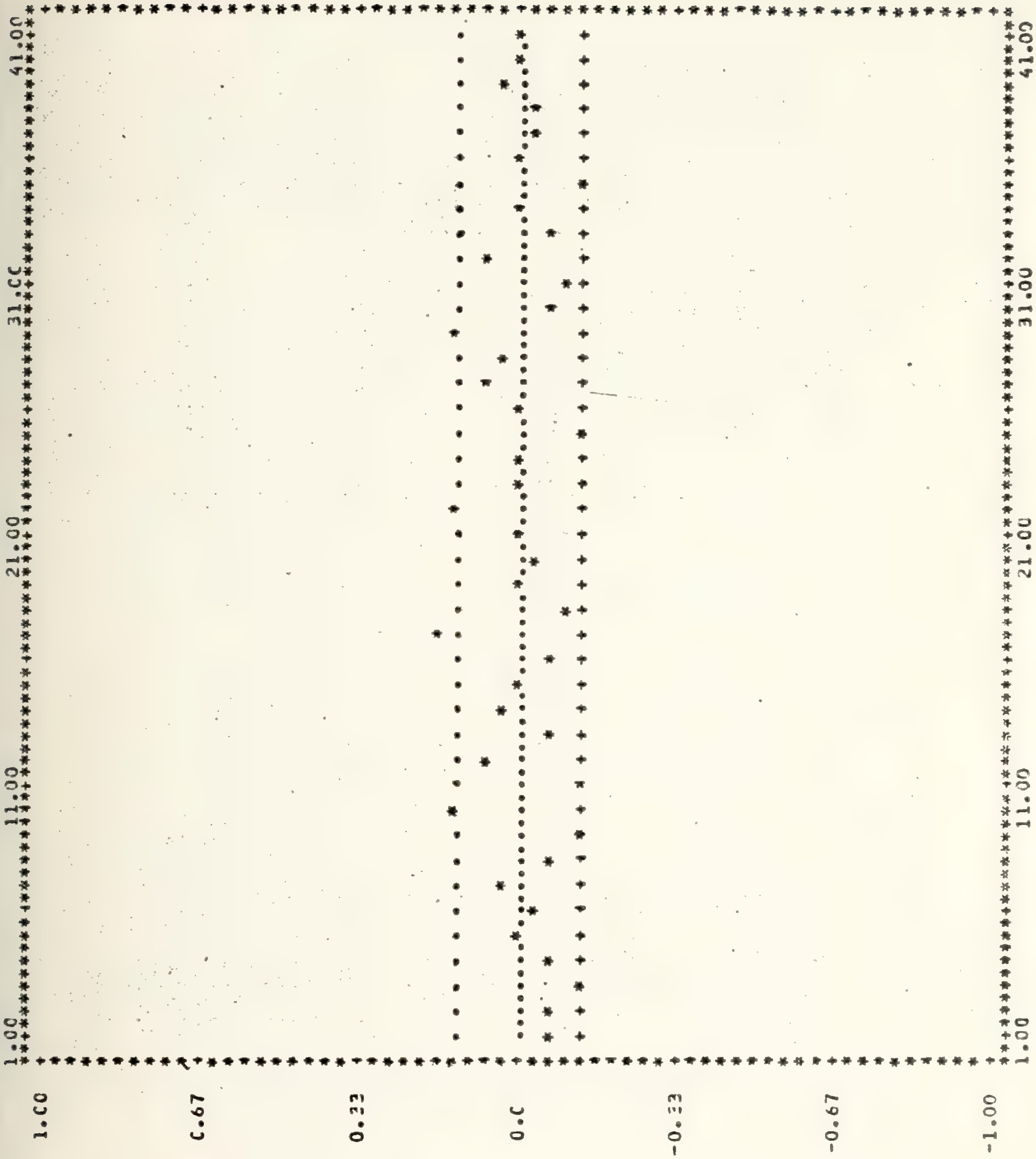
AUTOCORRELATIONS

-0.079	-0.065	-0.122	-0.063	0.013	-0.018	0.049	-0.052	-0.124	0.122
-0.122	0.072	-0.077	0.029	-0.011	-0.058	0.171	-0.101	-0.013	-0.020
-0.007	0.135	0.014	-0.013	-0.135	-0.009	0.043	0.039	0.131	-0.058
-0.110	0.070	-0.052	0.007	-0.149	0.002	-0.034	-0.043	0.025	0.009

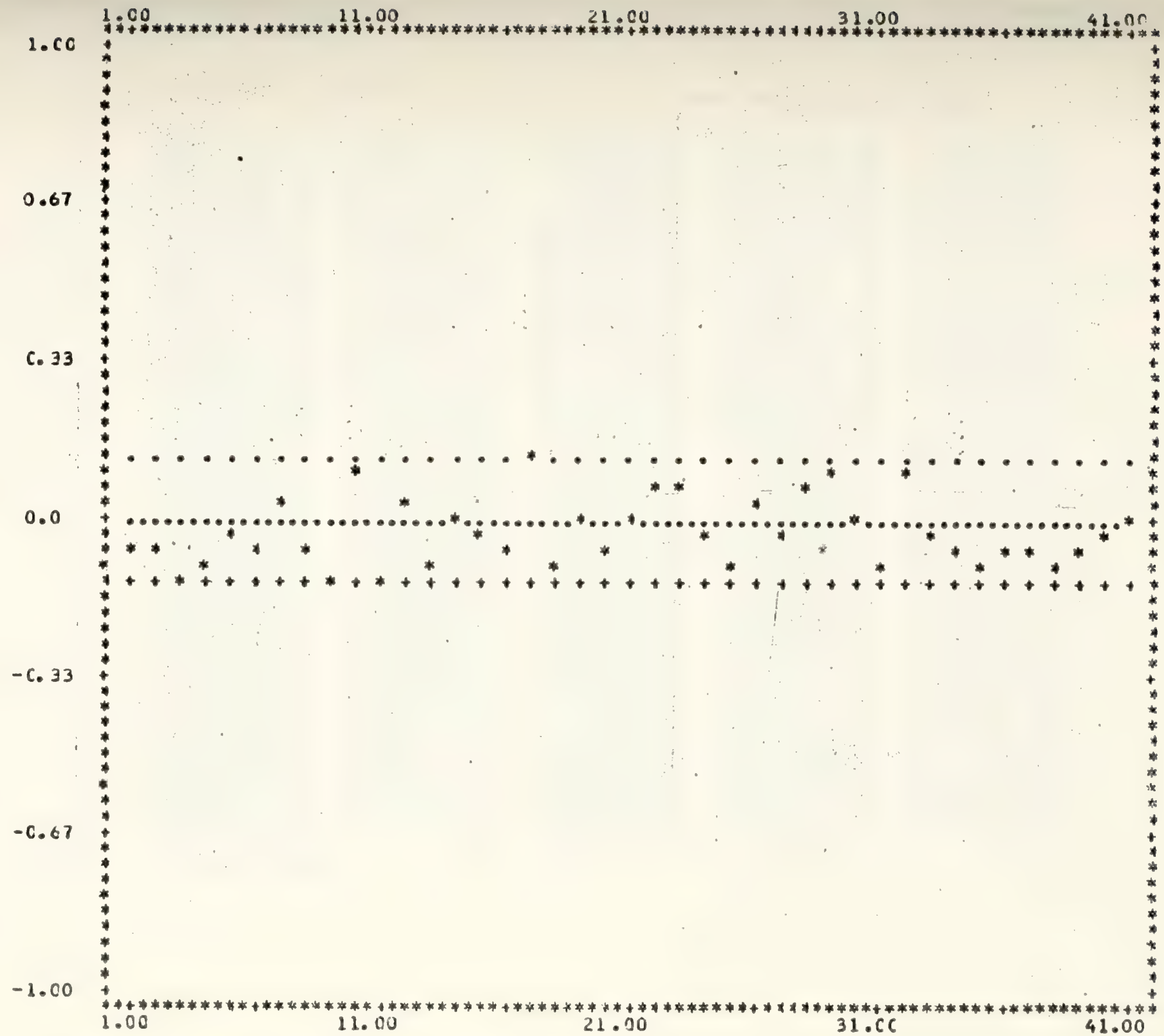
PARTIAL AUTOCORRELATIONS

-0.079	-0.072	-0.135	-0.094	-0.022	-0.051	0.022	-0.060	-0.145	0.094
-0.143	0.023	-0.089	-0.005	-0.039	-0.074	0.130	-0.105	-0.014	-0.053
0.004	0.081	0.056	-0.041	-0.059	0.025	-0.023	0.082	0.089	0.013
-0.089	0.102	-0.038	-0.061	-0.111	-0.071	-0.051	-0.058	-0.079	-0.047

MEAN=-.267666E-02 VARIANCE = 0.198143E-01



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTOS AND PAUTOS OF SERIES C DATA / TWO NONSEASONAL DIFFEREN

FILE: FILE FT03F001 P1 NAVAL POSTGRADUATE SCHOOL

224

0.0	0.0	0.267866E-02	0.304770E-02	-0.196551E 00
0.759851E-01	-0.123163E-01	-0.189180E 00	-0.124972E 00	0.160915E 00
0.866405E-02	-0.175265E 00	0.179652E 00	-0.195302E 00	-0.925056E-03
0.177231E 00	-0.730256E-01	0.155916E-01	-0.464905E-02	0.104066E 00
0.116405E 00	0.322215E-01	0.221923E-01	-0.900777E-01	-0.685481E-02
-0.994250E-02	0.405007E-03	-0.198536E 00	-0.124628E 00	-0.140234E 00
-0.327819E-01	0.279972E 00	0.236998E 00	0.716385E-01	0.432553E-01
0.179398E-01	0.107422E-01	0.106490E 00	0.318746E 00	-0.139615E 00
-0.752262E-01	0.742220E-01	0.315260E-02	0.127191E-01	-0.951511E-01
-0.878178E-02	-0.106656E-01	0.432880E-04	0.101282E 00	0.116629E 00
-0.681146E-01	0.839755E-02	-0.497881E-02	0.306604E-02	0.202468E 00
0.730566E 00	-0.570365E 00	-0.481147E 00	-0.337558E 00	0.193819E 00
0.285612E 00	0.167159E 00	0.262729E 00	0.360547E 00	0.863945E-01
0.613344E-01	-0.277675E 00	-0.276266E-01	-0.337125E 00	0.526567E-01
-0.133774E 00	-0.208923E 00	-0.143437E 00	-0.144172E 00	-0.357932E-01
-0.209264E-01	-0.484429E-02	-0.701432E-03	-0.980518E-01	0.890848E-01
0.224166E-02	0.114526E 00	0.118754E 00	0.338857E-01	0.227412E-01
0.102044E-01	-0.929734E-01	0.191204E 00	-0.830367E-01	0.160242E-01
-0.587767E-02	-0.394610E-02	0.102466E 00	-0.826986E-01	-0.954382E-01
-0.211903E-01	-0.125972E-01	0.981870E-01	-0.185424E 00	0.898510E-01
-0.108970E 00	0.993037E-01	0.224956E-02	0.115852E 00	0.169315E-01
0.203048E-01	0.753019E-02	0.206400E 00	-0.678630E-01	-0.799761E-01
0.828786E-01	-0.962670E-01	-0.958467E-01	-0.235413E-01	-0.135231E-01
-0.102227E 00	-0.131584E-01	-0.123859E-01	-0.748755E-03	0.965102E-03
0.271733E-02	-0.196816E 00	-0.241002E-01	0.738510E-01	0.209741E 00
0.141139E 00	-0.506934E-01	0.140056E-01	-0.197839E-02	0.204234E 00
-0.694459E-01	0.119576E 00	0.101660E-01	-0.180432E 00	-0.120853E 00
0.626298E-01	0.956472E-01	0.239749E-01	0.183805E-01	0.108325E 00
-0.180026E 00	0.919240E-01	-0.107984E 00	0.997082E-01	0.102408E 00
0.297282E-01	0.220046E 00	-0.631572E-01	0.122508E 00	-0.188642E 00
-0.741514E-02	0.177200E 00	0.261308E-01	0.292340E-01	0.101089E-01
0.786098E-02	0.105063E 00	-0.818183E-01	0.205023E 00	-0.179678E 00
-0.295502E 00	0.138672E 00	-0.316510E 00	0.770389E-01	-0.277366E-01
0.684385E-02	-0.997043E-01	-0.991144E-02	-0.115963E-01	-0.219068E-03
0.116051E-02	0.102801E 00	0.169922E-01	0.183458E-01	0.740891E-02
0.607756E-02	0.447639E-02	-0.959227E-01	0.900493E-01	-0.197346E 00
0.187160E 00	-0.971237E-01	0.113565E 00	-0.942560E-01	0.104405E 00
0.464440E-02	-0.831258E-01	-0.814583E-02	0.907868E-01	-0.858601E-01
0.102609E 00	-0.943206E-01	0.202997E 00	-0.181553E 00	0.103981E 00
-0.653548E-02	-0.847335E-01	0.901432E-01	-0.958913E-01	0.115336E-02
0.904131E-01	0.152846E-01	0.116511E 00	-0.792940E-01	-0.931485E-01
-0.204183E-01	0.187773E 00	-0.740889E-01	-0.831785E-01	-0.184005E-01
-0.110630E 00	0.850424E-01	-0.999364E-01	-0.658152E-04	-0.102852E-01
-0.198759E 00	-0.126029E 00	-0.404497E-01	-0.119222E 00	0.810003E-01
0.983743E-01	0.226744E 00	0.146676E 00	-0.477415E-01	

RESIDUAL VALUES.

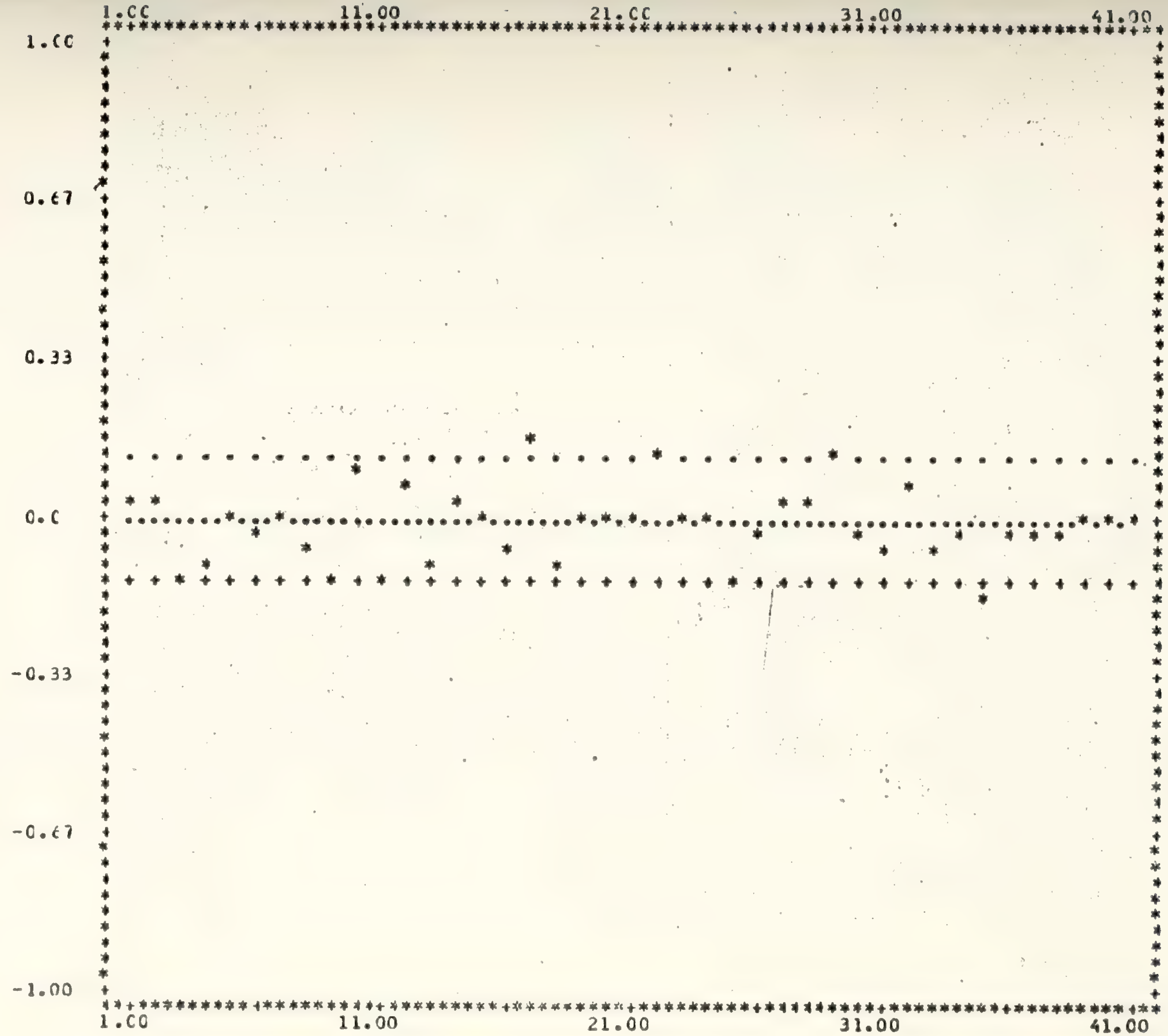
AUTOCORRELATIONS

0.019	0.024	-0.134	-C.053	-0.012	-0.043	0.005	-0.063	-0.125	0.088
-0.142	C.069	-0.098	0.025	0.004	-0.055	0.157	-0.090	0.CC5	-0.006
0.009	0.123	0.CC5	-C.015	-0.133	-0.019	0.049	0.C43	0.123	-0.035
-0.078	0.058	-0.078	-0.C15	-0.171	-C.028	-0.049	-0.035	C.C03	0.006

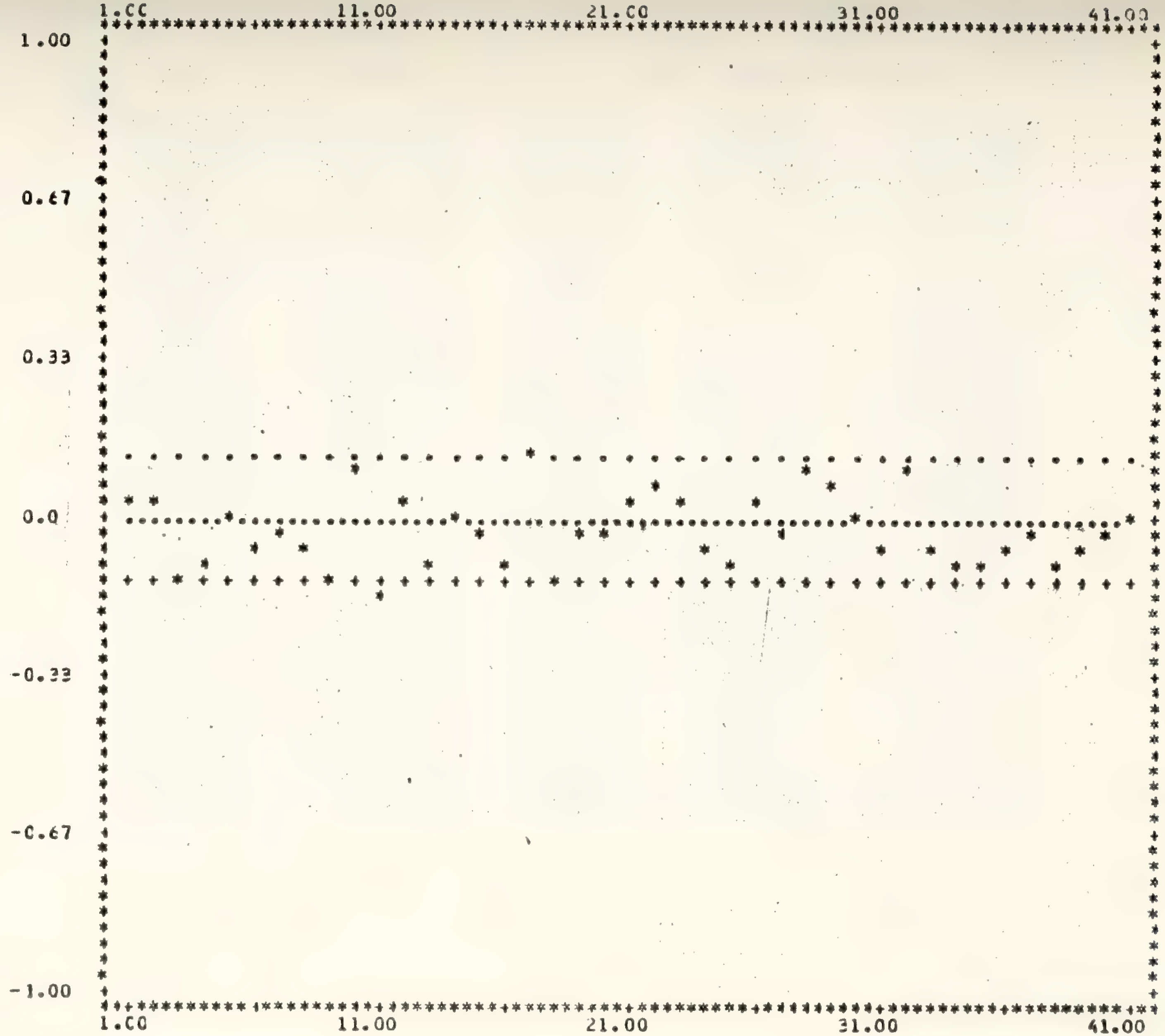
PARTIAL AUTOCORRELATIONS

C.C19	C.033	-0.135	-C.090	0.001	-0.055	-0.019	-0.C71	-C.143	0.087
-0.166	C.017	-0.104	-0.013	-0.025	-C.089	C.123	-0.123	-0.021	-0.025
0.024	0.065	0.024	-C.065	-0.102	0.040	-0.019	0.085	C.C56	0.C05
-C.C79	0.103	-0.056	-0.088	-0.112	-0.067	-0.043	-0.101	-0.078	-0.036

MEAN=C.236684E-02 VARIANCE = 0.189503E-01



AUTOCORRELATICNS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
ALTOS AND PALTOS OF RESIDUALS / ARIMA(0,2,2) MODEL OF SERIES

225

0.0	-0.216273E 00	-0.740475E-01	0.667891E-02	0.667891E-02
-0.193318E 00	0.681382E-01	-0.125731E-01	-0.212598E 00	-0.151111E 00
0.129558E 00	-0.318405E-01	-0.231850E 00	0.129613E 00	-0.231865E 00
-0.703721E-01	0.129613E 00	-0.131859E 00	-0.511199E-01	-0.511199E-01
0.488861E-01	0.681382E-01	-0.125731E-01	-0.126006E-01	-0.112579E 00
-0.318527E-01	-0.318527E-01	-0.318677E-01	-0.231838E 00	-0.170390E 00
-0.196658E 00	-0.108904E 00	0.191072E 00	0.148877E 00	-0.125731E-01
-0.126006E-01	-0.125731E-01	-0.126006E-01	0.874176E-01	0.306682E 00
-0.135534E 00	-0.740475E-01	0.106685E 00	0.259462E-01	0.259310E-01
-0.740475E-01	0.667891E-02	0.667891E-02	0.667891E-02	0.106685E 00
0.125937E 00	-0.547605E-01	0.259310E-01	0.259584E-01	0.259310E-01
0.225955E 00	0.764474E 00	-0.500657E 00	-0.435522E 00	-0.231865E 00
0.229631E 00	0.287402E 00	0.145217E 00	0.264475E 00	0.403012E 00
0.160793E 00	0.160820E 00	-0.139195E 00	0.103009E 00	-0.196994E 00
0.145217E 00	-0.355283E-01	-0.154786E 00	-0.933118E-01	-0.112592E 00
-0.318677E-01	-0.318405E-01	-0.319527E-01	-0.318527E-01	-0.131859E 00
0.488861E-01	-0.318527E-01	0.681382E-01	0.874176E-01	0.667891E-02
0.667891E-02	0.667891E-02	-0.933270E-01	0.187424E 00	-0.740598E-01
0.667891E-02	0.667891E-02	0.667891E-02	0.106685E 00	-0.740598E-01
-0.933270E-01	-0.125883E-01	-0.125731E-01	0.874053E-01	-0.193318E 00
0.681382E-01	-0.112579E 00	0.681382E-01	-0.125731E-01	0.874053E-01
0.667891E-02	0.667891E-02	0.667891E-02	0.206676E 00	-0.547957E-01
-0.740475E-01	0.106685E 00	-0.740598E-01	-0.933270E-01	-0.125731E-01
-0.126006E-01	-0.112579E 00	-0.318527E-01	-0.318527E-01	-0.318677E-01
-0.318405E-01	-0.318527E-01	-0.231850E 00	-0.703993E-01	0.296188E-01
0.148892E 00	0.874053E-01	-0.933270E-01	-0.125731E-01	-0.126006E-01
0.187424E 00	-0.740598E-01	0.106670E 00	0.259584E-01	-0.174066E 00
-0.112579E 00	0.681382E-01	0.874176E-01	0.667891E-02	0.667891E-02
0.106685E 00	-0.174066E 00	0.874176E-01	-0.933118E-01	0.874053E-01
0.106670E 00	0.259584E-01	0.225943E 00	-0.355283E-01	0.145217E 00
-0.135534E 00	0.259534E-01	0.225943E 00	0.644777E-01	0.644627E-01
0.644898E-01	0.644777E-01	0.164469E 00	-0.162488E-01	0.264475E 00
-0.969876E-01	-0.235525E 00	0.206676E 00	-0.254777E 00	0.874053E-01
0.667891E-02	0.667891E-02	-0.933270E-01	-0.125883E-01	-0.125731E-01
-0.126006E-01	-0.125731E-01	0.874053E-01	0.667891E-02	0.667891E-02
0.667891E-02	0.667891E-02	0.667891E-02	-0.933270E-01	0.874176E-01
-0.193318E 00	0.168144E 00	-0.933270E-01	0.874176E-01	-0.933118E-01
0.874053E-01	0.667891E-02	-0.933270E-01	-0.125883E-01	0.874176E-01
-0.933118E-01	0.874053E-01	-0.933270E-01	0.187424E 00	-0.174066E 00
0.874176E-01	0.667891E-02	-0.933118E-01	0.874053E-01	-0.933270E-01
-0.125883E-01	0.874176E-01	0.667891E-02	0.106685E 00	-0.740598E-01
-0.933270E-01	-0.125731E-01	0.187396E 00	-0.740475E-01	-0.933118E-01
-0.126006E-01	-0.112579E 00	0.681382E-01	-0.112579E 00	-0.318527E-01
-0.318527E-01	-0.231865E 00	-0.170378E 00	-0.896515E-01	-0.185642E 00
-0.892493E-02	0.103395E-01	0.129625E 00	0.681534E-01	-0.112607E 00

RESIDUAL VALUES.

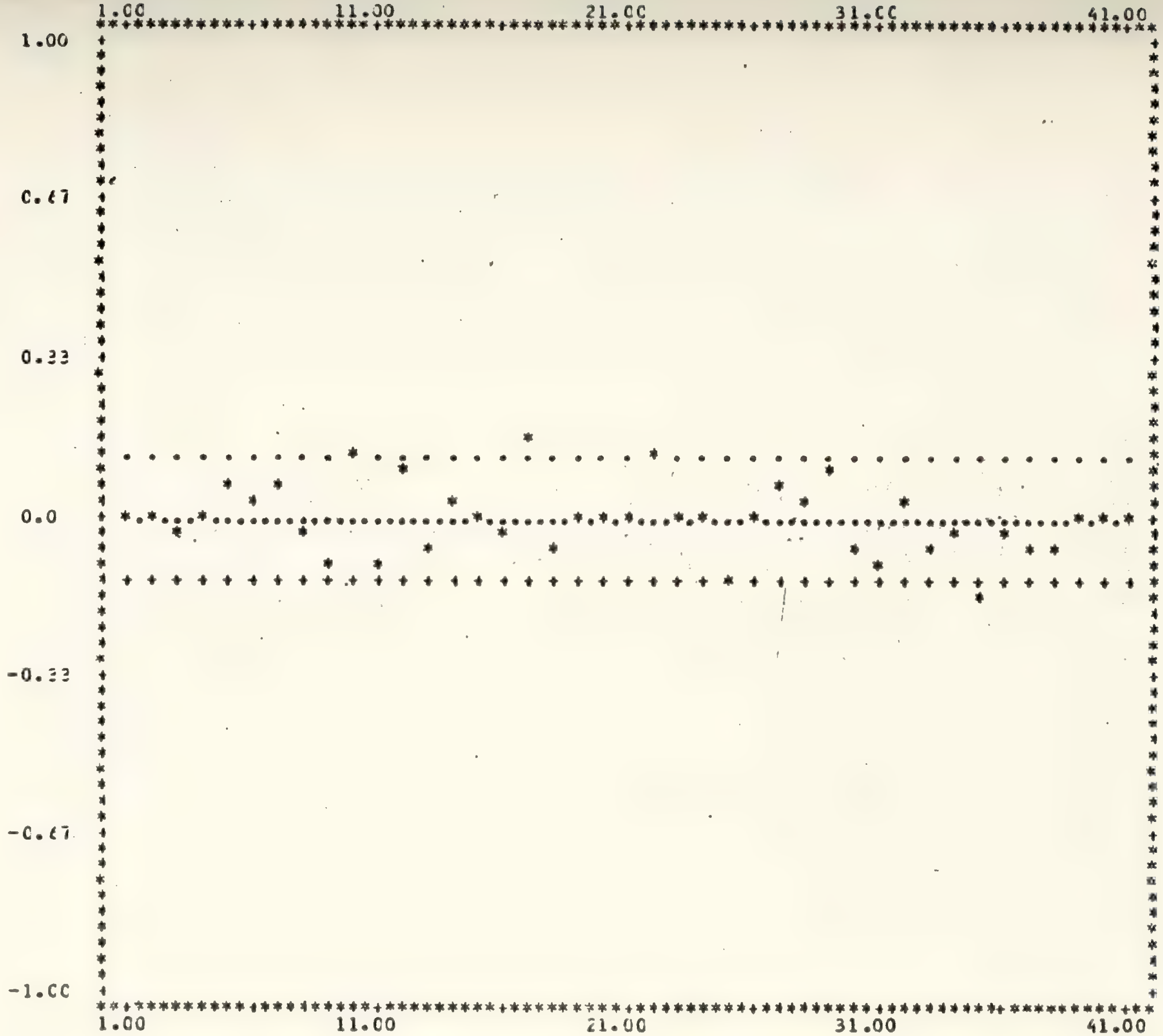
AUTOCORRELATIONS

0.016	0.014	-0.049	-0.005	0.061	0.024	0.078	-0.018	-0.087	0.130
-0.093	0.084	-0.055	0.043	0.007	-0.040	0.169	-0.079	-0.001	-0.010
0.000	0.129	0.014	-0.013	-0.127	-0.014	0.052	0.032	0.115	-0.060
-0.112	0.045	-0.073	-0.023	-0.166	-0.027	-0.056	-0.062	-0.002	-0.008

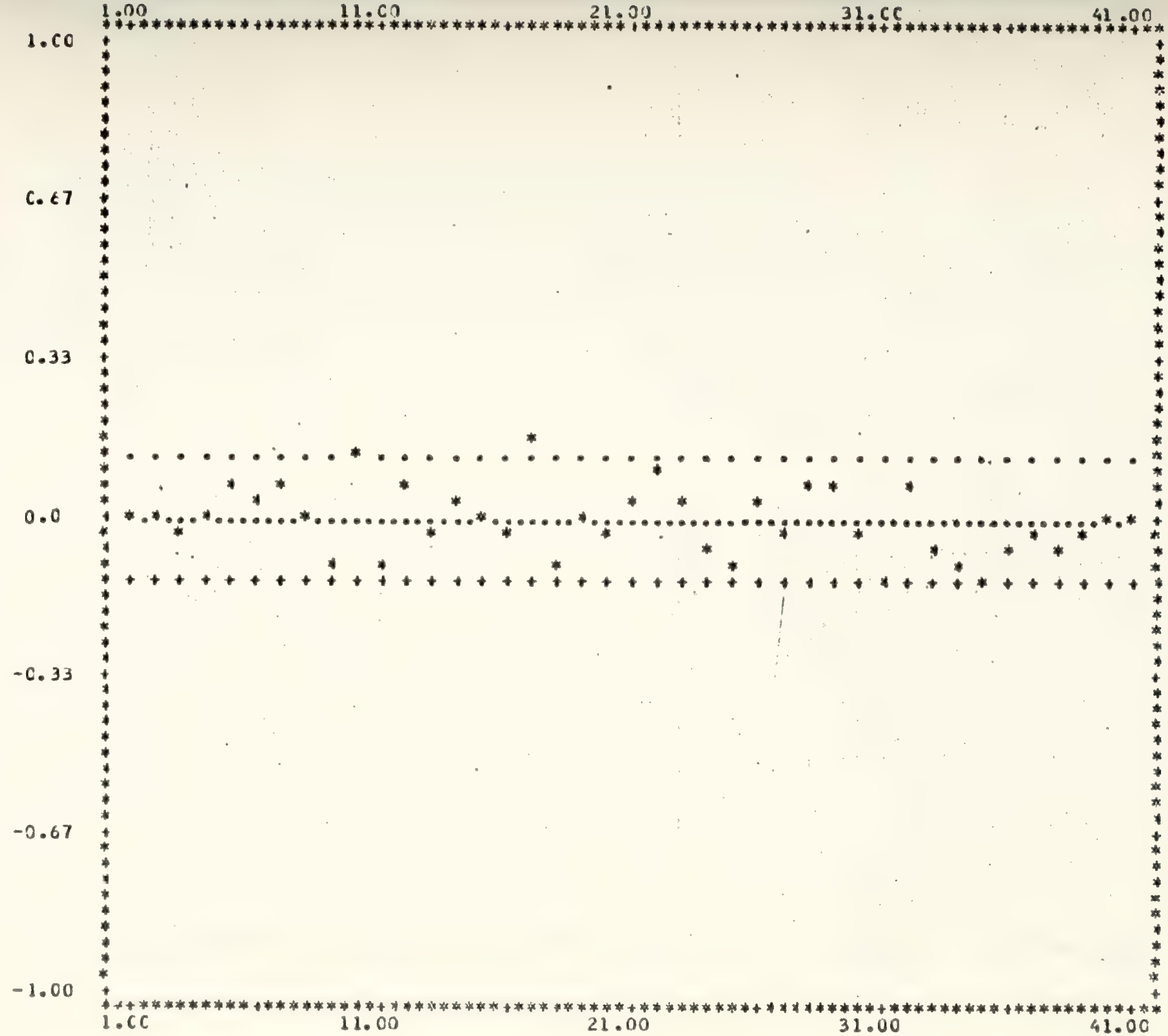
PARTIAL AUTOCORRELATIONS

0.016	0.014	-0.050	-0.004	0.063	0.019	0.075	-0.015	-0.087	0.140
-0.104	0.070	-0.048	0.042	0.003	-0.030	0.158	-0.088	0.013	-0.025
0.030	0.086	0.039	-0.062	-0.101	0.031	-0.021	0.077	0.058	-0.026
-0.117	0.070	-0.082	-0.052	-0.121	-0.059	-0.029	-0.065	-0.032	0.010

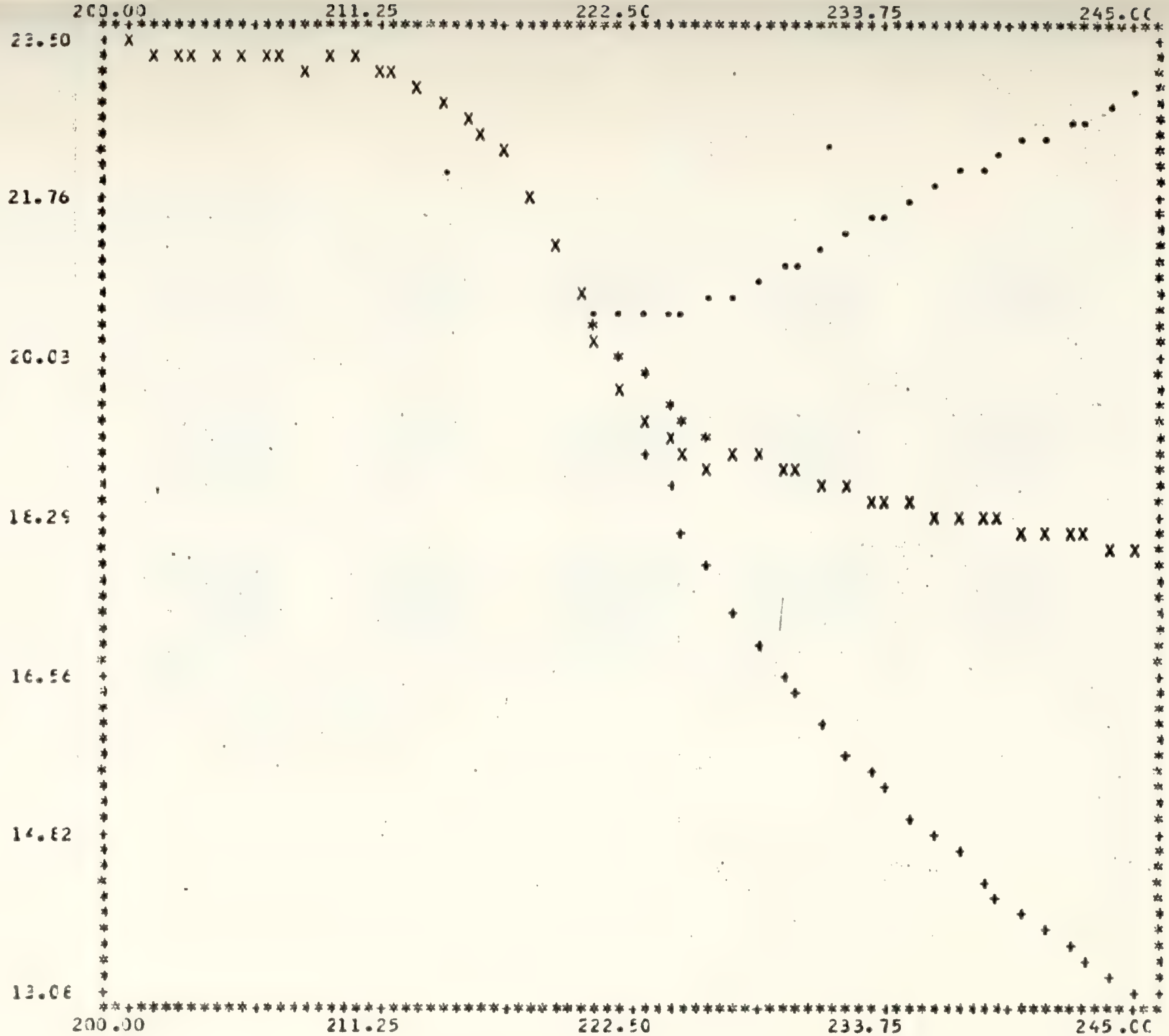
MEAN=-.252517E-02 VARIANCE = 0.177569E-01



ALTOCORRELATICNS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTCS AND PAUTOS OF RESIDUALS / ARIMA(1,1,0) MODEL OF SERIES



ORIGINAL AND FORECASTED TIME SERIES.

- . UPPER CONFIDENCE INTERVAL
- + LOWER CONFIDENCE INTERVAL
- * FORECASTS
- X ACTUAL DATA POINTS

FORECAST VALUES:

20.389648	20.051697	19.772186	19.539856	19.345612
19.182114	19.043442	18.924805	18.822342	18.732941
18.654083	18.583740	18.520264	18.462341	18.408890
18.359055	18.312134	18.267563	18.224899	18.183777
18.143890	18.105011	18.066940	18.029526	17.992630

UPPER CONFIDENCE LIMITS:

20.609390	20.505569	20.477859	20.503326	20.566162
20.655136	20.762131	20.881165	21.007858	21.138977
21.272141	21.405594	21.538086	21.668732	21.796890
21.922150	22.044220	22.162964	22.278336	22.390320
22.498532	22.604263	22.706421	22.805481	22.901581

LOWER CONFIDENCE LIMITS:

20.169891	19.557809	19.066498	18.576370	18.125046
17.709076	17.324738	16.968430	16.636810	16.326889
16.036011	15.761875	15.502427	15.255938	15.020880
14.755958	14.580039	14.372148	14.171455	13.977234
13.788843	13.605745	13.427455	13.253557	13.083674

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST ORIGIN:220

MAXIMUM FORECAST LEAD TIME: 25

APPENDIX C

KEYBOARD SESSION AND OUTPUT FROM THE ANALYSIS OF TIME SERIES G (SEASONAL)

This appendix contains the complete terminal keyboard session and all offline output from the analysis of Box and Jenkins' [Ref. 4] time series G (International airline passengers, monthly totals, Jan 1949 - Dec 1960) using the Time Series Editor. This appendix is intended to supplement the discussion of the analysis of series G given in Chapter VI of this report.

The terminal listings are presented first, followed by the computer offline output.

```
repeat login  nur@pn@

login 1621p44 400k
ENTER PASSWORD:

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:
0444r172
READY AT 15.12.34 ON 09/16/78
CMS Version 3.25

CP
link 2069p 191 192
ENTER PASSWORD:

SET TO READ ONLY

ipl cms
CMS Version 3.25

login 191
R;
login 192 t,p
T (192) R/O
R;

timeser
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY *.

YOU HAVE ENTERED THE TIME SERIES EDITOR.

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING
WITH I THRU N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.

DO YOU WANT A LIST OF THE OPTIONS?
y
OPTION                        DESCRIPTION
GENERATE -----GENERATE ANY ARIMA TIME SERIES
AUTO ---------CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT ---------PLOT A TIME SERIES
ESTIMATE -----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
DIFF ---------DIFFERENCE A TIME SERIES
FORECAST -----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
TRANS --------TRANSFORMS VALUES OF A TIME SERIES
ROOTS --------DETERMINES ROOTS OF ARIMA CHARACTERISTIC EQUATION
ZFORMAT ------ALTER DATA FILE TO FORMAT 5F15.6
CMSWORK ------PERFORM CP/CMS COMMANDS IN TIMESER EXEC
SIMULATE -----SIMULATE NONSEASONAL TIME SERIES
YESTSEAS -----CALCULATE INITIAL SEASONAL PARAMETERS
WMARQRDT -----MARQUARDT SOLUTION FOR PARAMETER ESTIMATES
XSUMSQ -------CALCULATE SUM OF SQUARES FOR ARBITRARY PARAMETERS


WOULD YOU LIKE MORE INFO?
y

ENTER OPTION YOU WANT INFO ABOUT.
y

YESTSEAS ----THIS PROGRAM CALCULATES INITIAL PARAMETER ESTIMATES
FOR SEASONAL AND NONSEASONAL ARIMA MODELS, TO BE USED AS INPUTS TO
THE WMARQRDT PROGRAM.


DO YOU WANT INFO ABOUT ANOTHER OPTION?
y
ENTER OPTION YOU WANT INFO ABOUT.
w
```

```
WMARQRDT ----THIS PROGRAM CALCULATES NON-LINEAR LEAST SQUARES
ESTIMATES OF BOX-JENKINS PARAMETERS FOR A GENERAL (SEASONAL
OR NONSEASONAL) ARIMA MODEL.  IT REQUIRES INITIAL PARAMETER
ESTIMATES AS STARTING VALUES; THESE MAY BE CALCULATED USING
PROGRAM YESTSEAS.


DO YOU WANT INFO ABOUT ANOTHER OPTION?
y
ENTER OPTION YOU WANT INFO ABOUT.
x

XSUMSQ ------THIS PROGRAM CALCULATES THE SUM OF SQUARED RESIDUALS
FOR ANY SET OF ARIMA (SEASONAL OR NONSEASONAL) PARAMETERS.


DO YOU WANT INFO ABOUT ANOTHER OPTION?
n
*DO YOU WANT TO TRY A SESSION?
y

ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
stat
P (191): 26 FILES; 235 REC IN USE, 61 LEFT (of 296), 79% FULL (2 CYL)
cp q f
FILES:- NO RDR, NO PRT, NO PUN
listf * ft02f001
FILENAME FILETYPE MODE NO.REC. DATE
SERG     FT02F001  P1      3    9/16
SERC     FT02F001  P1      5    9/16
alter serg ft02f001 pl file ft02f001 pl
&goto -ques
DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.
p
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 ENTER TITLE FOR PLOT
series g data / undifferenced
 TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
a
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
               AUTOCORRELATIONS

 0.948  0.876  0.807  0.753  0.714  0.682  0.663  0.656  0.671  0.703
 0.743  0.760  0.713  0.646  0.586  0.538  0.500  0.469  0.450  0.442
 0.457  0.482  0.517  0.532  0.494


          PARTIAL AUTOCORRELATIONS

 0.948 -0.229  0.038  0.094  0.074  0.008  0.126  0.090  0.232  0.166
 0.171 -0.135 -0.540 -0.027  0.091  0.025  0.032  0.077  0.048 -0.046
 0.046 -0.100  0.052  0.048 -0.163
```

```
    MEAN= 280.299          VARIANCE =  14292.0

 ENTER TITLE FOR PLOTS.
autos and pautos of series g data / undifferenced
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
t
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 DO YOU WANT TO TRANSLATE THE ORIGIN: W=Z-SHIFT?
n
 DO YOU WANT TO RESCALE THE VALUES: W=Z*SCALE?
n
 DO YOU WANT A LOG TRANSFORMATION?
y
 TRANSFORMATION IS W(I)=LOG(SCALE*(Z(I)-SHIFT)-FACTOR) WHERE:

  SCALE= 1.00000       SHIFT=0.0            FACTOR=0.0
YOUR ORIGINAL SERIES IS IN DATA FT02F001 P1.
YOUR TRANSFORMED SERIES IS IN FILE FT02F001 P1.

DO YOU WANT TO PLOT THE TRANSFORMED VALUES?
y
EXECUTION BEGINS...
* ENTER TITLE FOR PLOT
plot of series g data / natural log transform
 TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE

DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
a
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

 0.954  0.899  0.851  0.808  0.779  0.756  0.738  0.727  0.734  0.744
 0.758  0.762  0.717  0.663  0.618  0.576  0.544  0.519  0.501  0.490
 0.498  0.506  0.517  0.520  0.484


         PARTIAL AUTOCORRELATIONS

 0.954 -0.118  0.054  0.024  0.116  0.044  0.038  0.100  0.204  0.064
 0.106 -0.042 -0.485 -0.034  0.042 -0.044  0.028  0.037  0.042  0.014
 0.073 -0.033  0.061  0.031 -0.194


    MEAN= 5.54218          VARIANCE = 0.193531

 ENTER TITLE FOR PLOTS.
autos and pautos of series g data / natural log transform
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
DO YOU WANT TO GO AGAIN?
y
```

```
ENTER LETTER FOR OPTION YOU WANT.
d
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 IS YOUR TIME SERIES SEASONAL?
y
 ENTER ORDER OF SEASONAL DIFFERENCING.
1
 ENTER LENGTH OF SEASONAL PERIOD VIA I2.
12
 ENTER NUMBER OF NONSEASONAL DIFFERENCES.
1
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

-0.341  0.105 -0.202  0.021  0.056  0.031 -0.056 -0.001  0.176 -0.076
 0.064 -0.387  0.152 -0.058  0.150 -0.139  0.071  0.016 -0.011 -0.117
 0.039 -0.091  0.223 -0.018 -0.100


         PARTIAL AUTOCORRELATIONS

-0.341 -0.013 -0.193 -0.125  0.033  0.035 -0.060 -0.020  0.226  0.043
 0.047 -0.339 -0.109 -0.077 -0.022 -0.140  0.026  0.115 -0.013 -0.167
 0.132 -0.072  0.143 -0.067 -0.103


    MEAN=0.290920E-03     VARIANCE = 0.208604E-02

 ENTER TITLE FOR PLOTS.
autos and pautos for series g s@data / 1 ns diff, 1 seas diff, ln xform
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
alter file ft03f001 pl save ft03f001 pl
alter data ft02f001 pl serg ft02f001 pl
stat
P (191): 29 FILES; 267 REC IN USE, 29 LEFT (of 296), 90% FULL (2 CYL)
erase file ft08f001
cp q f
FILES:- NO RDR, NO PRT, NO PUN
&goto -ques
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
y
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12
 ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
0
```

```
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1


 INITIAL PARAMETER ESTIMATES FOR MARQRT :


 THETA(1) =  0.390425
 THETAS(1) =  0.534397

DO YOU WANT TO GO AGAIN?
Y

ENTER LETTER FOR OPTION YOU WANT.
W
IS YOUR DATA IN FILE FT02F001?
Y
EXECUTION BEGINS...
 ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12

 NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

 ENTER NON-SEASONAL MA PARAMETER THETA(1).
.390425
 ENTER SEASONAL MA PARAMETER THETAS(1).
.534397
*

 CONVERGENCE HAS BEEN REACHED IN MAX( 7, 7)  ITERATIONS.


 SELECTED OUTPUT FOLLOWS:


           PARAMETER ESTIMATE              STANDARD ERROR


           THETA(1) =  0.377152            0.819933D-01
           THETAS(1) =  0.572387           0.780252D-01


           MOVING AVERAGE CONSTANT: THETA0 =    0.000291


**

           CHI-SQUARE STATISTIC FOR RESIDUAL LACK OF FIT = 29.713571

           DEGREES OF FREEDOM = 38

           PROBABILITY OF EXCEEDING STATISTIC =  0.829438
```

```
 DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
 y
EXECUTION BEGINS...
               AUTOCORRELATIONS

 0.009  0.026 -0.129 -0.105  0.078  0.077 -0.036 -0.033  0.103 -0.050
 0.026 -0.020  0.013  0.035  0.067 -0.130  0.052  0.015 -0.093 -0.090
-0.027 -0.014  0.213  0.009 -0.042


          PARTIAL AUTOCORRELATIONS

 0.009  0.026 -0.130 -0.104  0.088  0.068 -0.072 -0.029  0.151 -0.057
-0.022  0.018  0.046  0.001  0.053 -0.114  0.069  0.029 -0.129 -0.134
 0.042 -0.014  0.143 -0.025  0.013


   MEAN=0.236005E-02     VARIANCE = 0.139713E-02

 ENTER TITLE FOR PLOTS.
autos and pautos of residuals / (0,1,1)x(0,1,1)12 model of series g
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
*
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
y
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12
 ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
1
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
***

 INITIAL PARAMETER ESTIMATES FOR MARQRT :


 PHI(1) =  0.112699
 THETA(1) =  0.490883
 THETAS(1) =  0.533679

DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
w
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
1
```

```
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12

 NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

 ENTER NON-SEASONAL AR PARAMETER PHI(1).
0.112699
 ENTER NON-SEASONAL MA PARAMETER THETA(1).
0.490883
 ENTER SEASONAL MA PARAMETER THETAS(1).
0.533679
***

 CONVERGENCE HAS BEEN REACHED IN MAX(10,10)  ITERATIONS.


 SELECTED OUTPUT FOLLOWS:

          PARAMETER ESTIMATE              STANDARD ERROR


          PHI(1) =  0.146667              0.224464D 00
          THETA(1) =  0.509816            0.195934D 00
          THETAS(1) =  0.573388           0.784896D-01


          MOVING AVERAGE CONSTANT: THETA0 =    0.000248



          CHI-SQUARE STATISTIC FOR RESIDUAL LACK OF FIT = 28.302543

          DEGREES OF FREEDOM = 37

          PROBABILITY OF EXCEEDING STATISTIC =  0.847102
DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
y
*EXECUTION BEGINS...
                 AUTOCORRELATIONS

-0.013  0.073 -0.100 -0.088  0.077  0.073 -0.031 -0.033  0.105 -0.054
 0.033 -0.018  0.014  0.027  0.070 -0.133  0.051  0.008 -0.092 -0.084
-0.020 -0.023  0.208  0.005 -0.036


            PARTIAL AUTOCORRELATIONS

-0.013  0.073 -0.098 -0.096  0.092  0.081 -0.064 -0.040  0.152 -0.050
-0.027  0.017  0.047 -0.004  0.053 -0.118  0.055  0.031 -0.123 -0.135
 0.051 -0.006  0.148 -0.019  0.003


    MEAN=0.253052E-02     VARIANCE = 0.139373E-02

 ENTER TITLE FOR PLOTS.
autos and pautos of residuals / (1,1,1)x(0,1,1)12 model of series g
 YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
 PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?
y
```

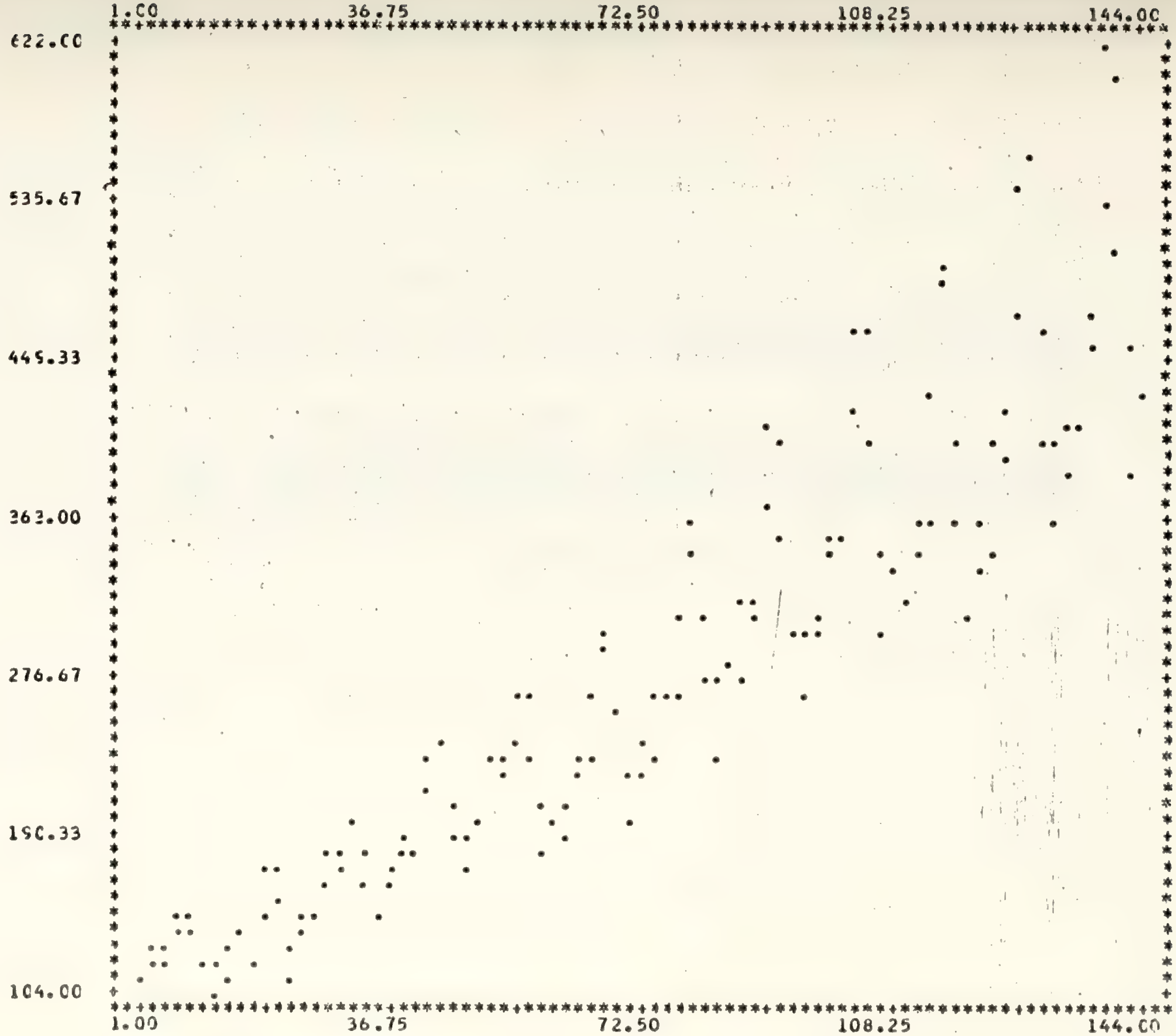
```
 ENTER LETTER FOR OPTION YOU WANT.
 f
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...

 IS YOUR SERIES SEASONAL?
y

 ENTER SEASONAL DATA AS REQUESTED:

 ENTER NUMBER OF SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12

 ENTER NONSEASONAL DATA AS REQUESTED:

 ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1

 NOW INPUT YOUR PARAMETER ESTIMATES:


 ENTER MA CONSTANT TERM, THETA0.
.000291
 ENTER NON-SEASONAL MA PARAMETER THETA(1).
.377152
 ENTER SEASONAL MA PARAMETER THETAS(1).
.572387
 ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.
30
 ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.
100
 ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.
131
 ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.
0.10

 WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?
y

 DO YOU WANT BASIC OUTPUT AT THE TERMINAL?
y

 THE LAST 10 WVEC VALUES:

 0.418999E 03  0.461001E 03  0.472000E 03  0.535001E 03  0.622000E 03
 0.606000E 03  0.507999E 03  0.461001E 03  0.390001E 03  0.432002E 03

 THE 30 FORECAST VALUES:

 0.398539E 03  0.415184E 03  0.395402E 03  0.462697E 03  0.450971E 03
 0.469710E 03  0.543456E 03  0.618194E 03  0.626276E 03  0.524292E 03
 0.460421E 03  0.405213E 03  0.448016E 03  0.466864E 03  0.444748E 03
 0.520593E 03  0.507548E 03  0.528791E 03  0.611991E 03  0.696357E 03
 0.705666E 03  0.590927E 03  0.519089E 03  0.456978E 03  0.505397E 03
 0.526812E 03  0.502002E 03  0.587782E 03  0.573220E 03  0.597386E 03
```

```
 THE 30 UPPER FORECAST CONFIDENCE LIMITS:

 0.399598E 03  0.416254E 03  0.396481E 03  0.463785E 03  0.452068E 03
 0.470813E 03  0.544567E 03  0.619311E 03  0.627399E 03  0.525422E 03
 0.461557E 03  0.406354E 03  0.449173E 03  0.468030E 03  0.445925E 03
 0.521779E 03  0.508743E 03  0.529995E 03  0.613203E 03  0.697577E 03
 0.706894E 03  0.592163E 03  0.520332E 03  0.458229E 03  0.506664E 03
 0.528090E 03  0.503292E 03  0.589083E 03  0.574532E 03  0.598708E 03

 ALPHA FOR THE CONFIDENCE LIMITS IS: 0.100
*
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
f

IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...

 IS YOUR SERIES SEASONAL?
y

 ENTER SEASONAL DATA AS REQUESTED:

 ENTER NUMBER OF SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12

 ENTER NONSEASONAL DATA AS REQUESTED:

 ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
1
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1

 NOW INPUT YOUR PARAMETER ESTIMATES:


 ENTER MA CONSTANT TERM, THETA0.
.000248
 ENTER NON-SEASONAL AR PARAMETER PHI(1).
0.146667
 ENTER NON-SEASONAL MA PARAMETER THETA(1).
0.509816
 ENTER SEASONAL MA PARAMETER THETAS(1).
0.573388
 ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.
30
 ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.
100
 ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.
131
 ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.
0.10

 WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?
y

 DO YOU WANT BASIC OUTPUT AT THE TERMINAL?
y
```

```
THE LAST 10 WVEC VALUES:

0.418999E 03  0.461001E 03  0.472000E 03  0.535001E 03  0.622000E 03
0.606000E 03  0.507999E 03  0.461001E 03  0.390001E 03  0.432002E 03

THE 30 FORECAST VALUES:

0.398650E 03  0.414875E 03  0.395125E 03  0.462366E 03  0.450651E 03
0.469348E 03  0.543045E 03  0.617700E 03  0.625753E 03  0.523897E 03
0.460071E 03  0.404899E 03  0.447739E 03  0.466360E 03  0.444325E 03
0.520096E 03  0.507066E 03  0.528257E 03  0.611381E 03  0.695632E 03
0.704905E 03  0.590336E 03  0.518566E 03  0.456512E 03  0.504960E 03
0.526113E 03  0.501400E 03  0.587074E 03  0.572532E 03  0.596632E 03

THE 30 UPPER FORECAST CONFIDENCE LIMITS:

0.399709E 03  0.415945E 03  0.396204E 03  0.463452E 03  0.451744E 03
0.470448E 03  0.544151E 03  0.618812E 03  0.626870E 03  0.525020E 03
0.461199E 03  0.406032E 03  0.448887E 03  0.467517E 03  0.445491E 03
0.521270E 03  0.508249E 03  0.529448E 03  0.612579E 03  0.696837E 03
0.706117E 03  0.591556E 03  0.519792E 03  0.457745E 03  0.506207E 03
0.527371E 03  0.502668E 03  0.588353E 03  0.573821E 03  0.597930E 03

ALPHA FOR THE CONFIDENCE LIMITS IS: 0.100

DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
f

IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...

 IS YOUR SERIES SEASONAL?
y

ENTER SEASONAL DATA AS REQUESTED:

ENTER NUMBER OF SEASONAL DIFFERENCES.
1
ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
ENTER LENGTH OF SEASON VIA FORMAT I2.
12

ENTER NONSEASONAL DATA AS REQUESTED:

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.
1
ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
0
ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1

NOW INPUT YOUR PARAMETER ESTIMATES:


ENTER MA CONSTANT TERM, THETA0.
.000291
ENTER NON-SEASONAL MA PARAMETER THETA(1).
.377152
ENTER SEASONAL MA PARAMETER THETAS(1).
.572387
ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.
40
```

```
 ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.
075
 ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.
120
 ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.
0.10

 WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?
y

 DO YOU WANT BASIC OUTPUT AT THE TERMINAL?
n
*
DO YOU WANT TO GO AGAIN?
y
ENTER LETTER FOR OPTION YOU WANT.
d
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
 IS YOUR TIME SERIES SEASONAL?
y
 ENTER ORDER OF SEASONAL DIFFERENCING.
1
 ENTER LENGTH OF SEASONAL PERIOD VIA I2.
12
 ENTER NUMBER OF NONSEASONAL DIFFERENCES.
1
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
n
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
c
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
WHEN FINISHED TYPE: &GOTO -QUES
alter file ft02f001 pl lnserg ft02f001 pl
alter file ft03f001 pl file ft02f001 pl
&goto -ques
DO YOU WANT TO GO AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
x
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...


 IS YOUR SERIES SEASONAL?
y
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1

 NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

 ENTER NON-SEASONAL MA PARAMETER THETA(1).
.377152
 ENTER SEASONAL MA PARAMETER THETAS(1).
.572387
```

```
        FOR THE GIVEN INPUT PARAMETERS AND MODEL

        THE RESIDUAL SUM OF SQUARES IS:         0.18192935D 00


 DO YOU WANT TO TEST DIFFERENT PARAMETER VALUES?
n


 DO YOU WANT TO TEST A DIFFERENT MODEL?
y


 IS YOUR SERIES SEASONAL?
y
 ENTER LENGTH OF SEASON VIA FORMAT I2.
12
 ENTER NUMBER OF SEASONAL AR PARAMETERS.
0
 ENTER NUMBER OF SEASONAL MA PARAMETERS.
1
 ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
1
 ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
1

 NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

 ENTER NON-SEASONAL AR PARAMETER PHI(1).
.146667
 ENTER NON-SEASONAL MA PARAMETER THETA(1).
.509816
 ENTER SEASONAL MA PARAMETER THETAS(1).
.573388
*

         FOR THE GIVEN INPUT PARAMETERS AND MODEL

         THE RESIDUAL SUM OF SQUARES IS:         0.18164378D 00



 DO YOU WANT TO TEST DIFFERENT PARAMETER VALUES?
n


 DO YOU WANT TO TEST A DIFFERENT MODEL?
n

DO YOU WANT TO GO AGAIN?
n
CONTROL RETURNED TO CMS
R;
```



X-SCALE: "*"= 0.179E 01 UNITS

Y-SCALE: "*"= 0.863E 01 UNITS
SERIES G DATA / UNDIFFERENCED

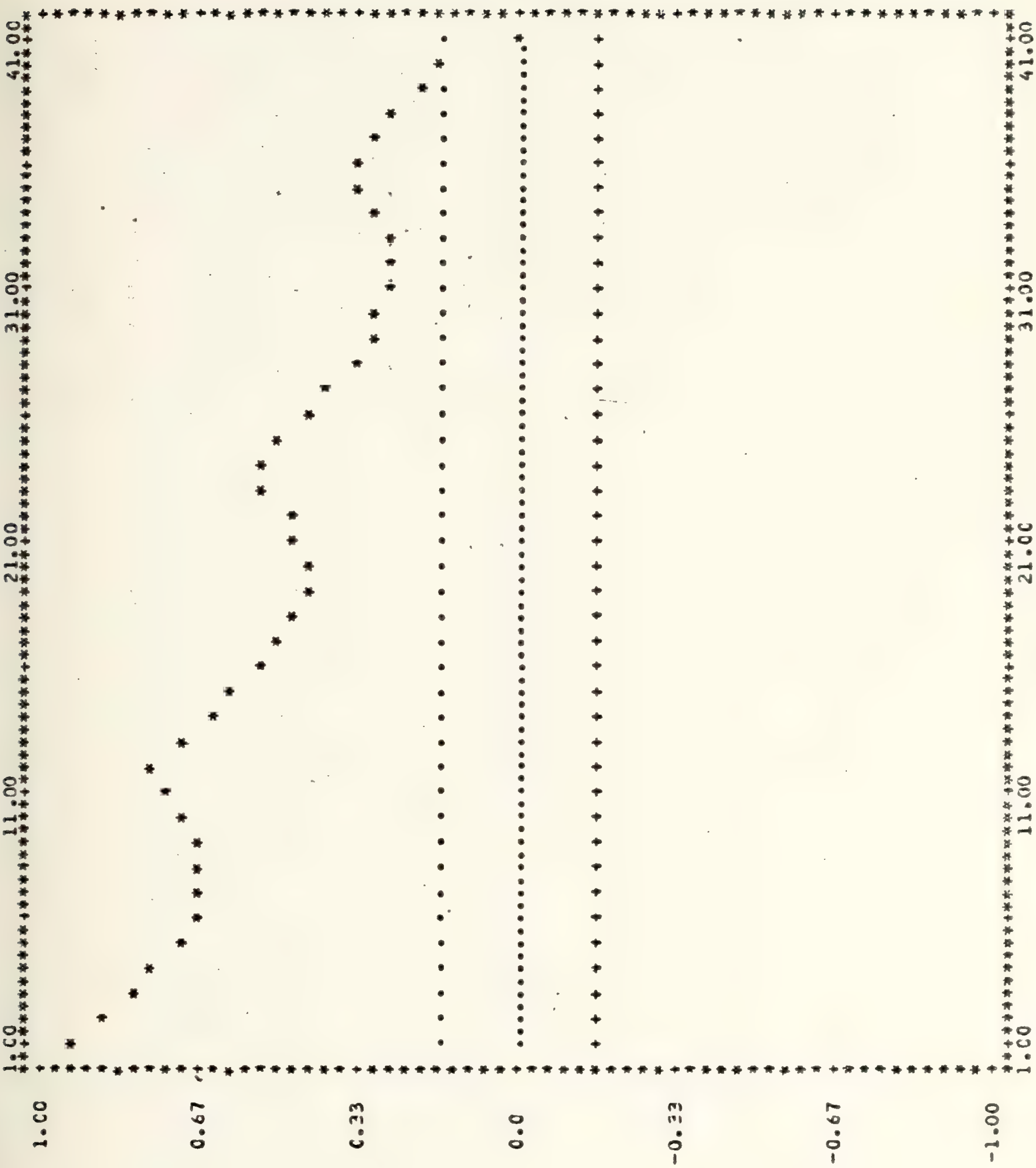
AUTOCORRELATIONS

0.948	0.876	0.807	0.753	0.714	0.682	0.663	0.656	0.671	0.703
0.743	0.760	0.713	0.646	0.586	0.538	0.500	0.469	0.450	0.442
0.457	0.482	0.517	0.532	0.494	0.438	0.388	0.348	0.315	0.288
0.271	0.264	0.277	0.299	0.326	0.337	0.303	0.254	0.211	0.172

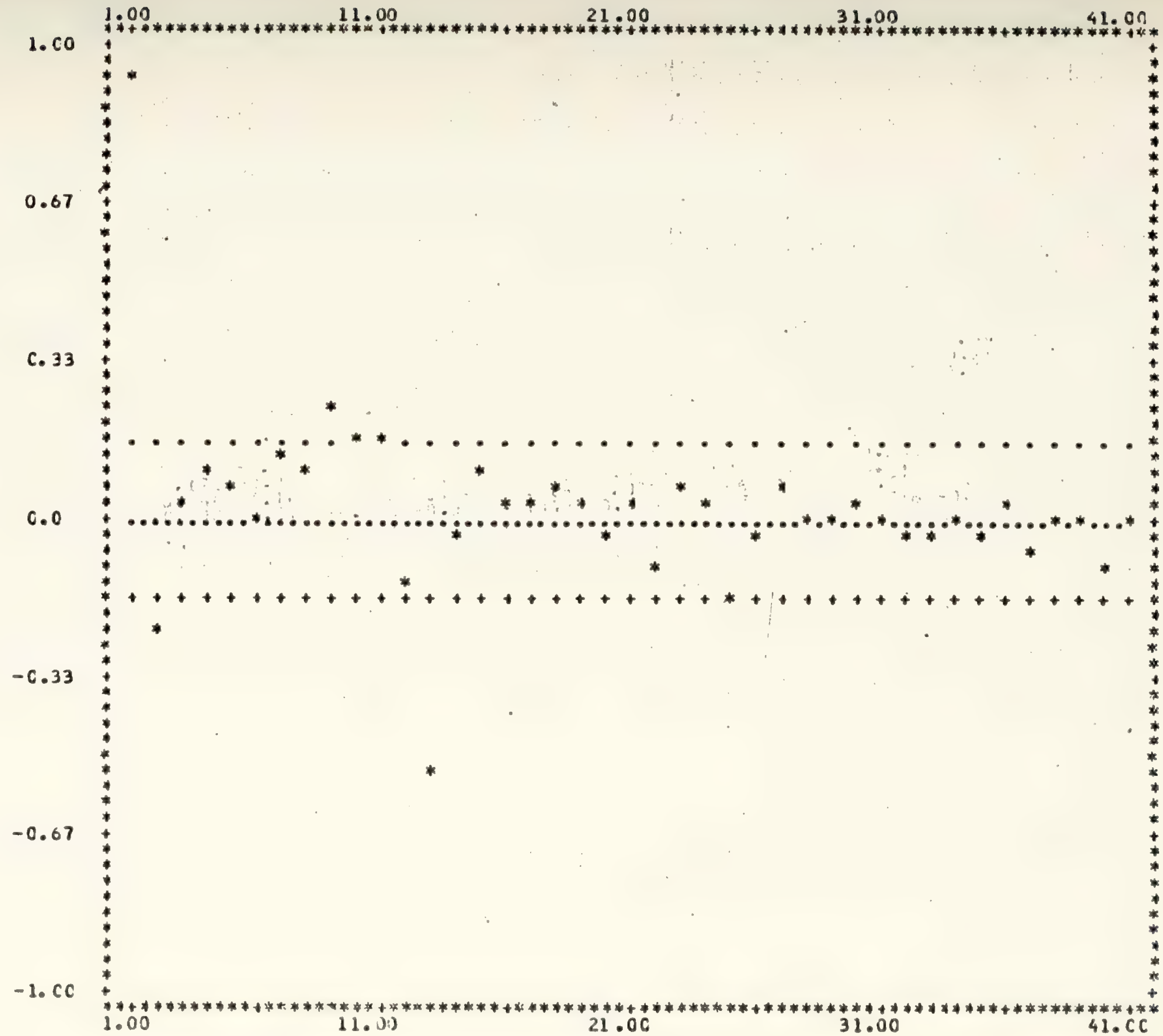
PARTIAL AUTOCORRELATIONS

0.948	-0.229	0.038	0.094	0.074	0.008	0.126	0.090	0.232	0.166
0.171	-0.135	-0.540	-0.027	0.091	0.025	0.032	0.073	0.048	-0.046
0.046	-0.100	0.052	0.048	-0.163	-0.036	0.066	0.006	0.008	0.019
-0.010	-0.018	-0.029	-0.015	-0.048	0.046	-0.067	-0.002	0.016	-0.088

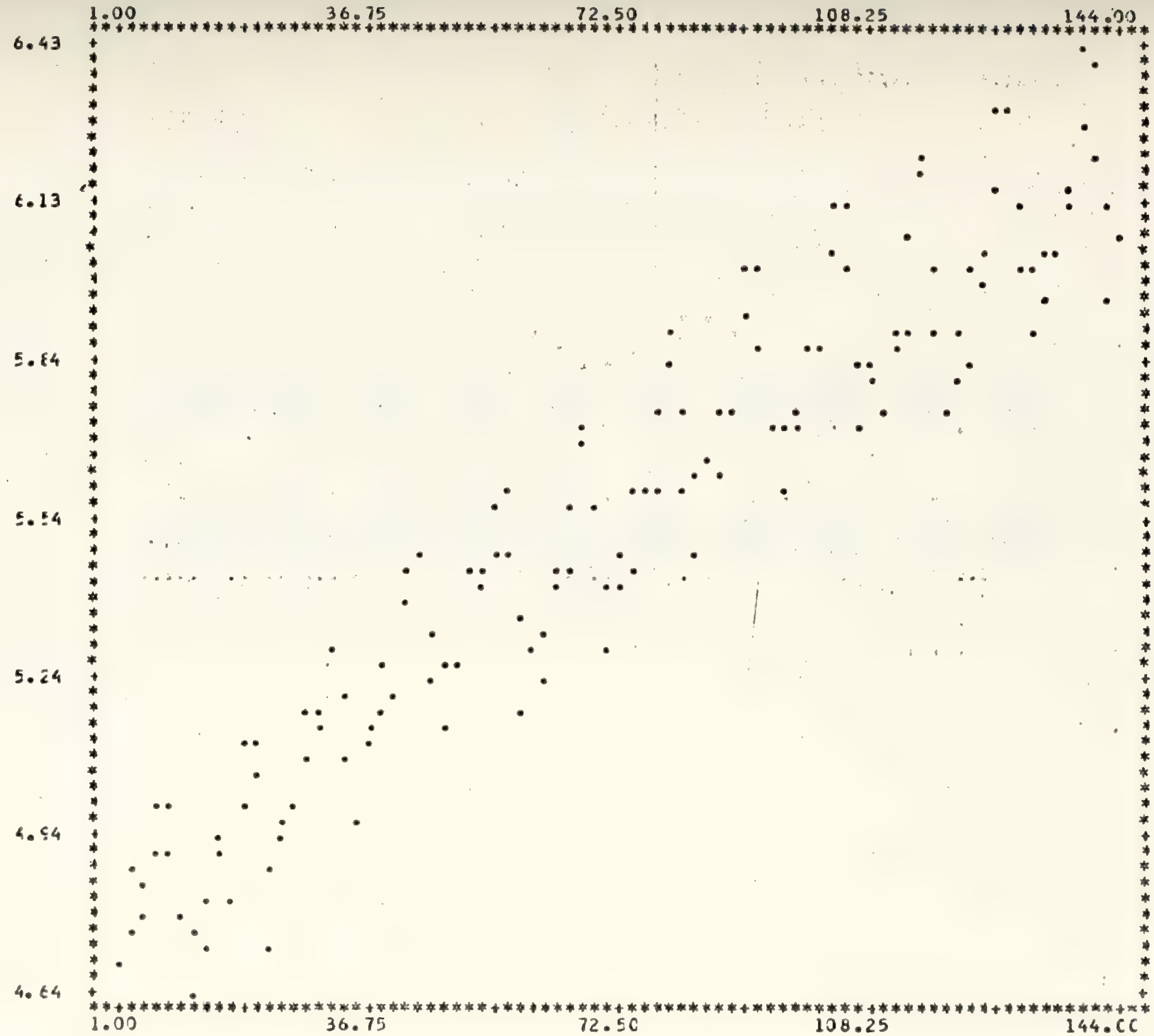
MEAN= 280.299 VARIANCE = 14292.0



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTOS AND PAUTOS OF SERIES G DATA / UNDIFFERENCED



X-SCALE: "*"= 0.179E C1 UNITS

Y-SCALE: "*"= 0.298E-01 UNITS
PLOT OF SERIES G DATA / NATURAL LOG TRANSFORM

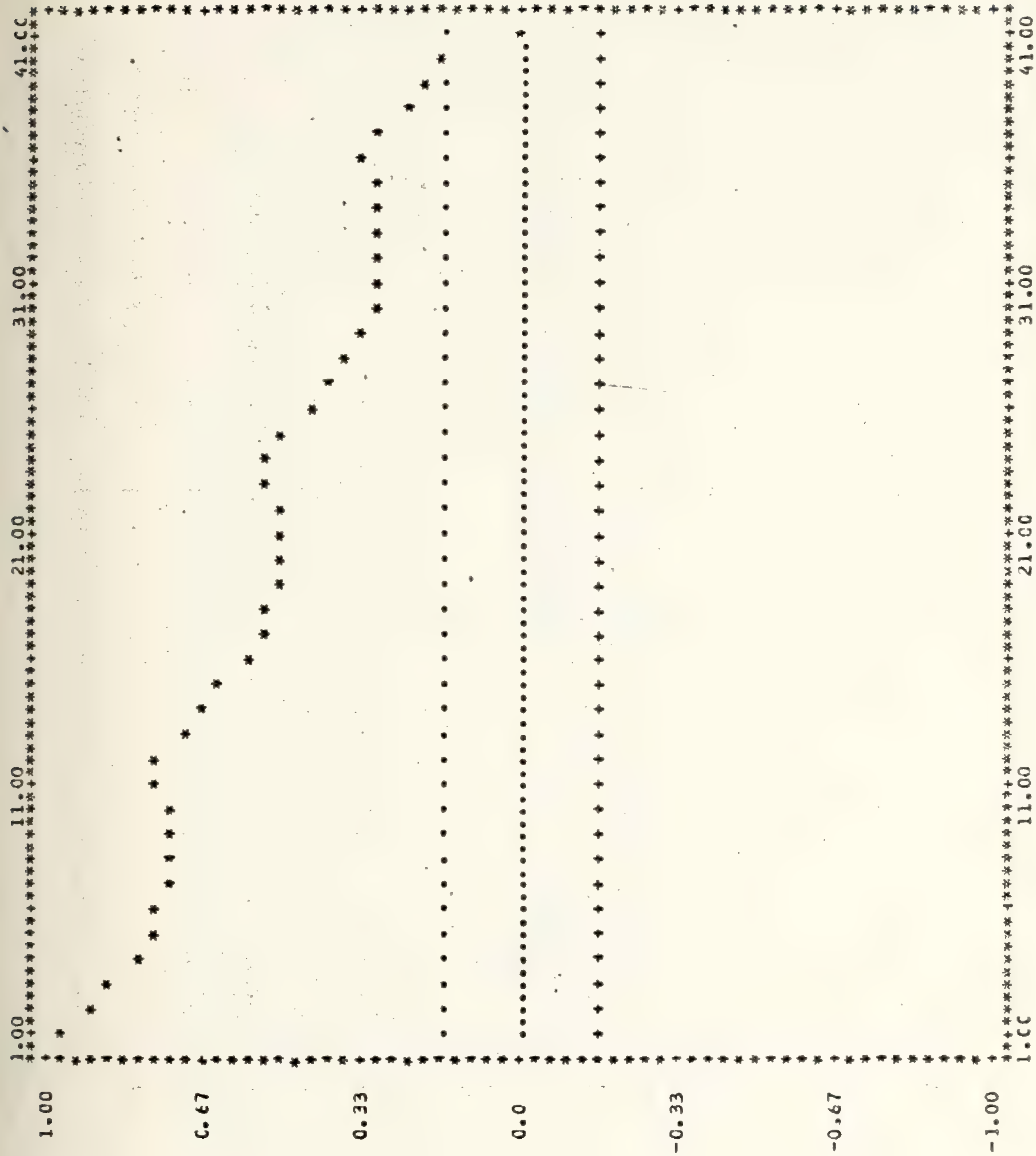
AUTOCORRELATIONS

0.954	0.899	0.851	0.808	0.779	0.756	0.738	0.727	0.734	0.744
0.758	0.762	0.717	0.663	0.618	0.576	0.544	0.519	0.501	0.490
0.498	0.506	0.517	0.520	0.484	0.437	0.400	0.364	0.337	0.315
0.297	0.285	0.295	0.305	0.315	0.319	0.286	0.245	0.211	0.175

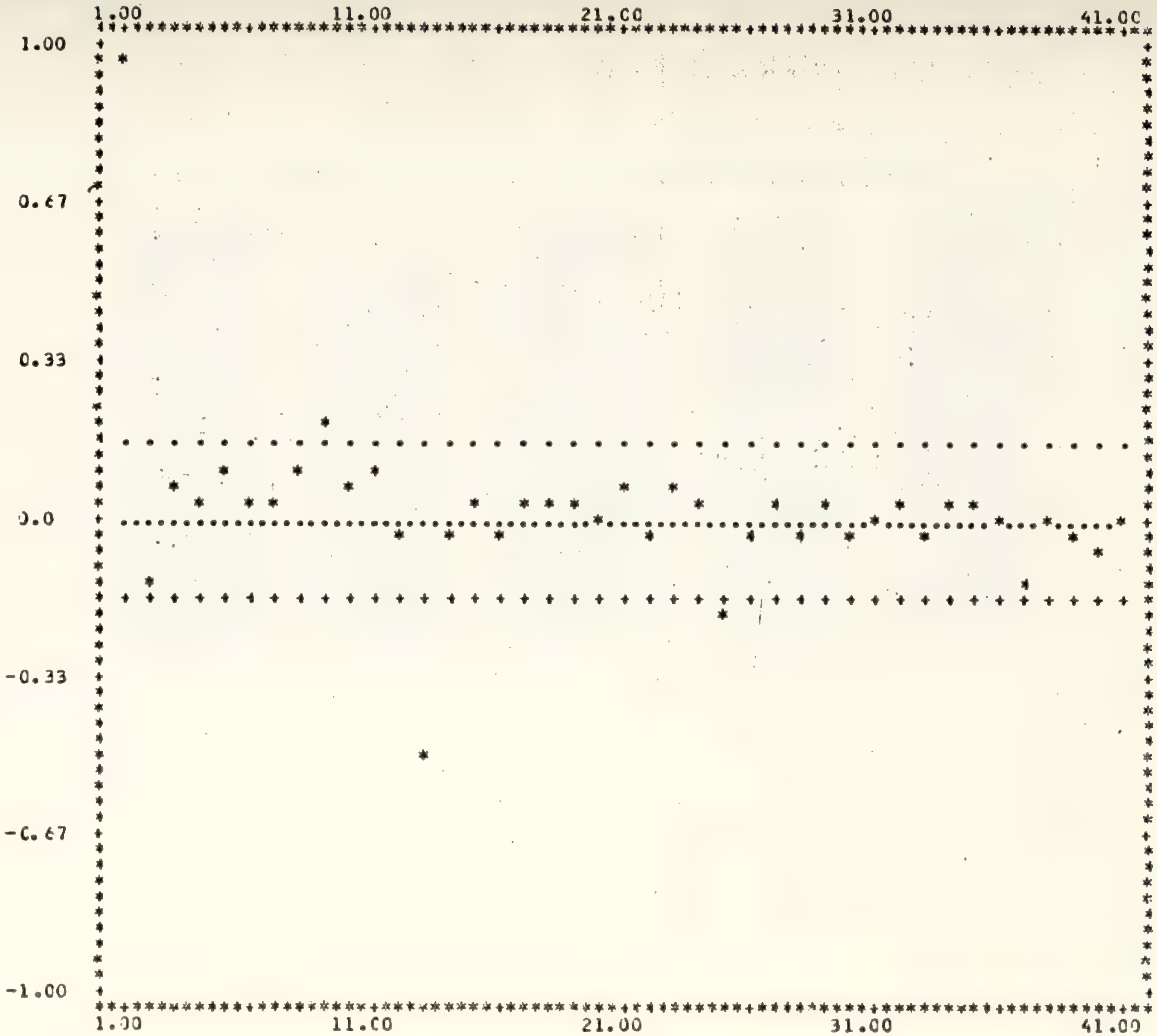
PARTIAL AUTOCORRELATIONS

0.954	-0.118	0.054	0.024	0.116	0.044	0.038	0.100	0.204	0.064
0.106	-0.042	-0.485	-0.034	0.042	-0.044	0.028	0.037	0.042	0.014
0.073	-0.033	0.061	0.031	-0.194	-0.035	0.036	-0.035	0.044	-0.045
-0.003	0.034	-0.020	0.028	0.029	-0.004	-0.132	-0.003	-0.025	-0.059

MEAN= 5.54218 VARIANCE = 0.193531



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



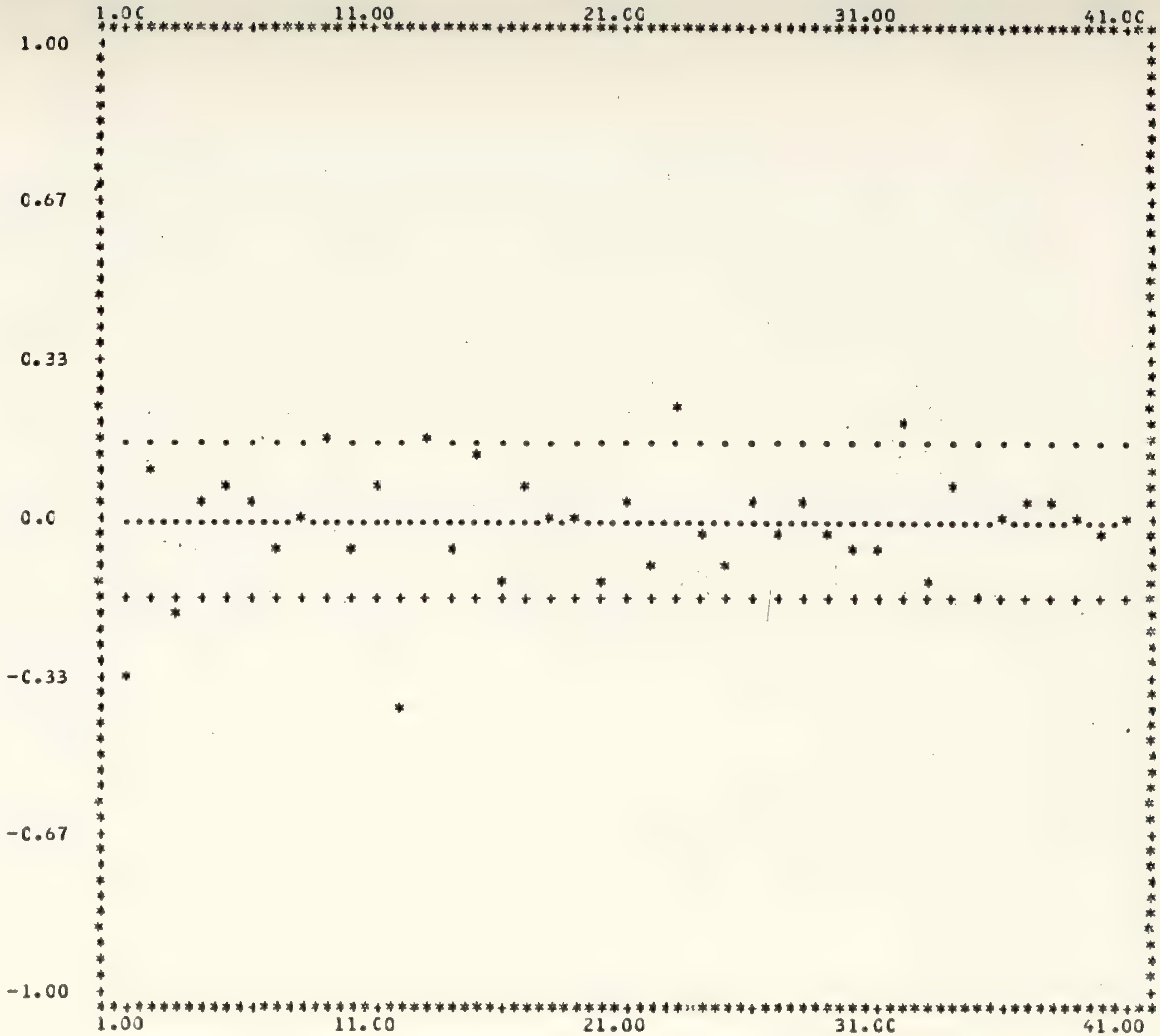
PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTCS AND PALTOS OF SERIES G DATA / LOG TRANSFORMED

FILE: FILE FT03F001 P1 NAVAL POSTGRADUATE SCHOOL

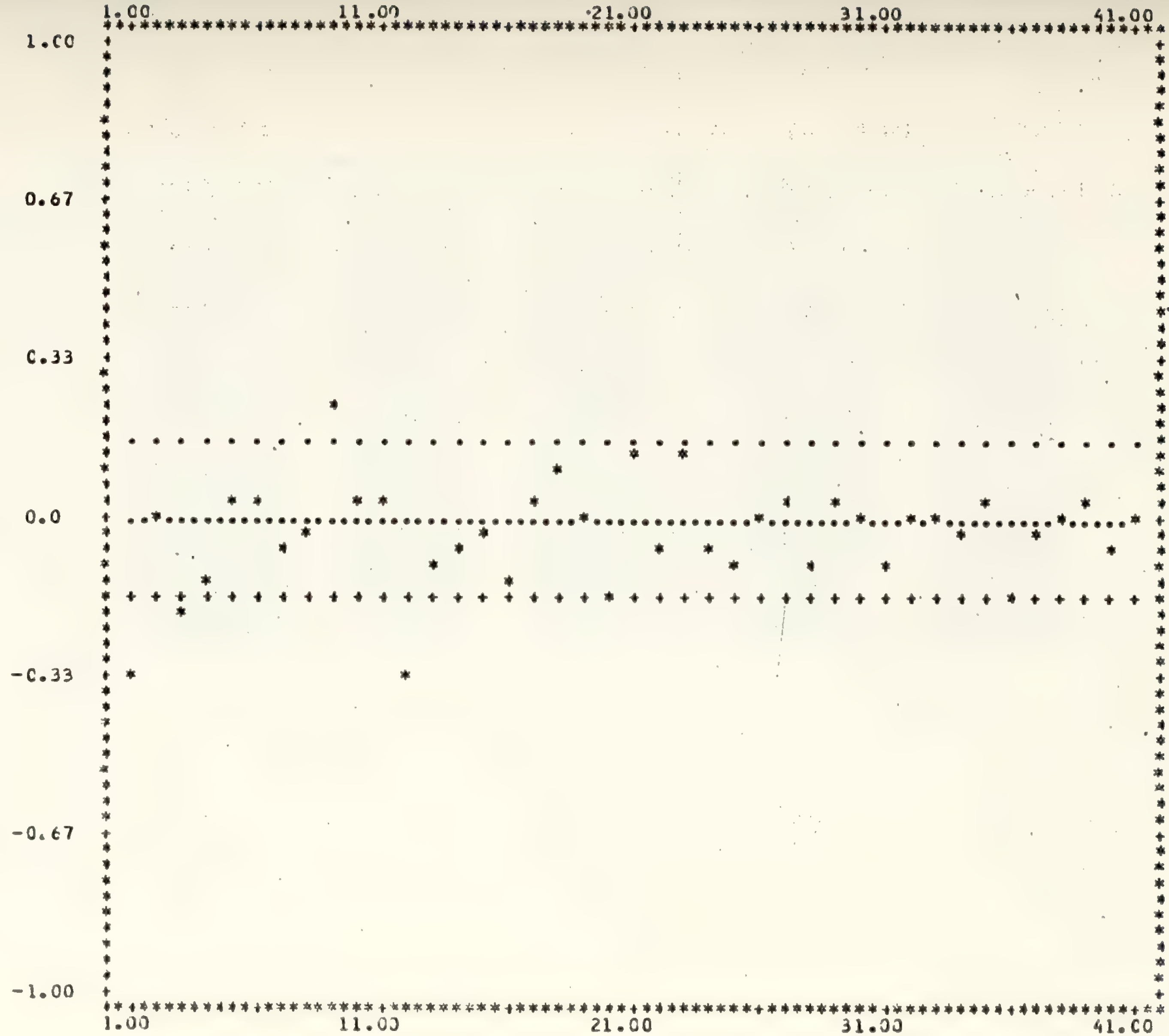
131

0.391703E-01	0.359535E-03	-0.205002E-01	-0.129404E-01	0.661602E-01
0.399103E-01	0.0	0.113602E-01	-0.387201E-01	-0.194197E-01
0.791502E-01	0.608397E-01	-0.574408E-01	0.586615E-01	-0.445404E-01
0.130700E 00	-0.141350E 00	-0.203304E-01	0.0	-0.516033E-02
0.449104E-01	0.501595E-01	-0.770597E-01	-0.541973E-02	0.173903E-01
-0.101411E 00	0.238400E-01	-0.427494E-01	0.140709E 00	-0.579250E-01
0.508595E-01	-0.682487E-01	0.372791E-01	-0.789642E-03	-0.801086E-02
-0.194197E-01	-0.513000E-01	0.115991E 00	0.599409E-01	-0.368865E-01
-0.115660E 00	0.292997E-01	-0.210094E-01	0.886917E-02	-0.261402E-01
-0.541191E-01	-0.100298E-01	0.456905E-02	-0.816793E-01	0.374298E-01
-0.304003E-01	0.562401E-01	0.612907E-01	0.515890E-01	-0.601101E-01
0.144005E-01	-0.659937E-02	0.383892E-01	0.101700E-01	0.404005E-01
0.437794E-01	-0.869398E-01	0.421000E-01	-0.266600E-01	0.335197E-01
0.101004E-01	-0.175591E-01	0.170088E-01	-0.675964E-02	-0.245600E-01
0.390501E-01	-0.338697E-01	0.129499E-01	-0.133038E-02	-0.201597E-01
0.121403E-01	0.805950E-02	-0.453892E-01	0.282583E-01	-0.254383E-01
-0.186605E-01	0.235996E-01	-0.380698E-01	0.762939E-02	-0.215097E-01
0.329399E-01	-0.100298E-01	0.407028E-02	0.106802E-01	-0.216103E-02
0.238514E-01	-0.131416E-01	-0.355911E-02	-0.755024E-02	-0.246706E-01
-0.171385E-01	-0.214405E-01	-0.382299E-01	-0.167103E-01	0.222797E-01
0.806046E-02	0.240602E-01	0.238295E-01	-0.782299E-01	0.339899E-01
-0.177298E-01	-0.132895E-01	0.541792E-01	0.156097E-01	0.419502E-01
0.144997E-01	0.166407E-01	-0.642204E-01	0.282097E-01	-0.824928E-02
0.347204E-01	-0.108213E-01	0.295811E-01	0.287390E-01	-0.368195E-01
-0.130892E-01	-0.102381E 00	0.120471E 00	-0.352612E-01	0.856018E-02
0.137043E-02	-0.459309E-01	0.120201E-01	0.318413E-01	-0.500813E-01
-0.996876E-02				

```
                AUTOCORRELATIONS

-0.341  0.105 -0.202  0.021  0.056  0.031 -0.056 -0.001  0.176 -0.076
 0.064 -0.387  0.152 -0.058  0.150 -0.139  0.071  0.016 -0.011 -0.117
 0.039 -0.051  0.223 -0.018 -0.100  0.049 -0.030  0.047 -0.018 -0.051
-0.054  0.196 -0.122  0.078 -0.152 -0.010  0.047  0.031 -0.015 -0.034

           PARTIAL AUTOCORRELATIONS

-0.341 -0.013 -0.193 -0.125  0.033  0.035 -0.060 -0.020  0.226  0.043
 0.047 -0.339 -0.109 -0.077 -0.022 -0.140  0.026  0.115 -0.013 -0.167
 0.132 -0.072  0.143 -0.067 -0.103 -0.010  0.044 -0.050  0.047 -0.005
-0.096 -0.015  0.011 -0.019  0.023 -0.165 -0.034  0.009  0.045 -0.077

    MEAN=0.290920E-03     VARIANCE = 0.208604E-02
```



ALTOCORRELATICNS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTOS AND PAUTOS OF SERIES G DATA / 1 NS DIFF, 1 SEAS DIFF,

131

0.391703E-01	0.359535E-03	-0.205002E-01	-0.129404E-01	0.661602E-01
0.399103E-01	0.0	0.113602E-01	-0.387201E-01	-0.194197E-01
0.791502E-01	0.608397E-01	-0.574408E-01	0.586615E-01	-0.445404E-01
0.130700E 00	-0.141350E 00	-0.203304E-01	0.0	-0.516033E-02
0.445104E-01	0.501595E-01	-0.770597E-01	-0.541973E-02	0.173903E-01
-0.101411E 00	0.238400E-01	-0.427494E-01	0.140709E 00	-0.579290E-01
0.508595E-01	-0.682487E-01	0.372791E-01	-0.789642E-03	-0.901036E-02
-0.194197E-01	-0.513000E-01	0.115991E 00	0.599499E-01	-0.368605E-01
-0.115660E 00	0.292997E-01	-0.210094E-01	0.886917E-02	-0.261412E-01
-0.541191E-01	-0.100298E-01	0.456905E-02	-0.816793E-01	0.374296E-01
-0.304003E-01	0.562401E-01	0.612907E-01	0.515890E-01	-0.601101E-01
0.144005E-01	-0.690537E-02	0.383892E-01	0.101700E-01	0.404005E-01
0.437794E-01	-0.869398E-01	0.421000E-01	-0.266600E-01	0.335197E-01
0.101004E-01	-0.175591E-01	0.170098E-01	-0.675964E-02	-0.245600E-01
0.390501E-01	-0.338697E-01	0.129499E-01	-0.133038E-02	-0.201597E-01
0.121403E-01	0.805550E-02	-0.453892E-01	0.282583E-01	-0.254283E-01
-0.186605E-01	0.235596E-01	-0.380898E-01	0.762939E-02	-0.205097E-01
0.329399E-01	-0.100298E-01	0.407028E-02	0.106802E-01	-0.216103E-02
0.238514E-01	-0.131416E-01	-0.355911E-02	-0.755024E-02	-0.246706E-01
-0.171385E-01	-0.214405E-01	-0.382299E-01	-0.167103E-01	0.222797E-01
0.806046E-02	0.240602E-01	0.238295E-01	-0.782299E-01	0.339899E-01
-0.177298E-01	-0.132895E-01	0.541792E-01	0.156097E-01	0.419502E-01
0.144997E-01	0.166407E-01	-0.642204E-01	0.282097E-01	-0.824928E-02
0.347204E-01	-0.108213E-01	0.295811E-01	0.287390E-01	-0.368195E-01
-0.130892E-01	-0.102381E 00	0.120471E 00	-0.352612E-01	0.856018E-02
0.137043E-02	-0.459309E-01	0.120201E-01	0.318413E-01	-0.500813E-01
-0.956876E-02				

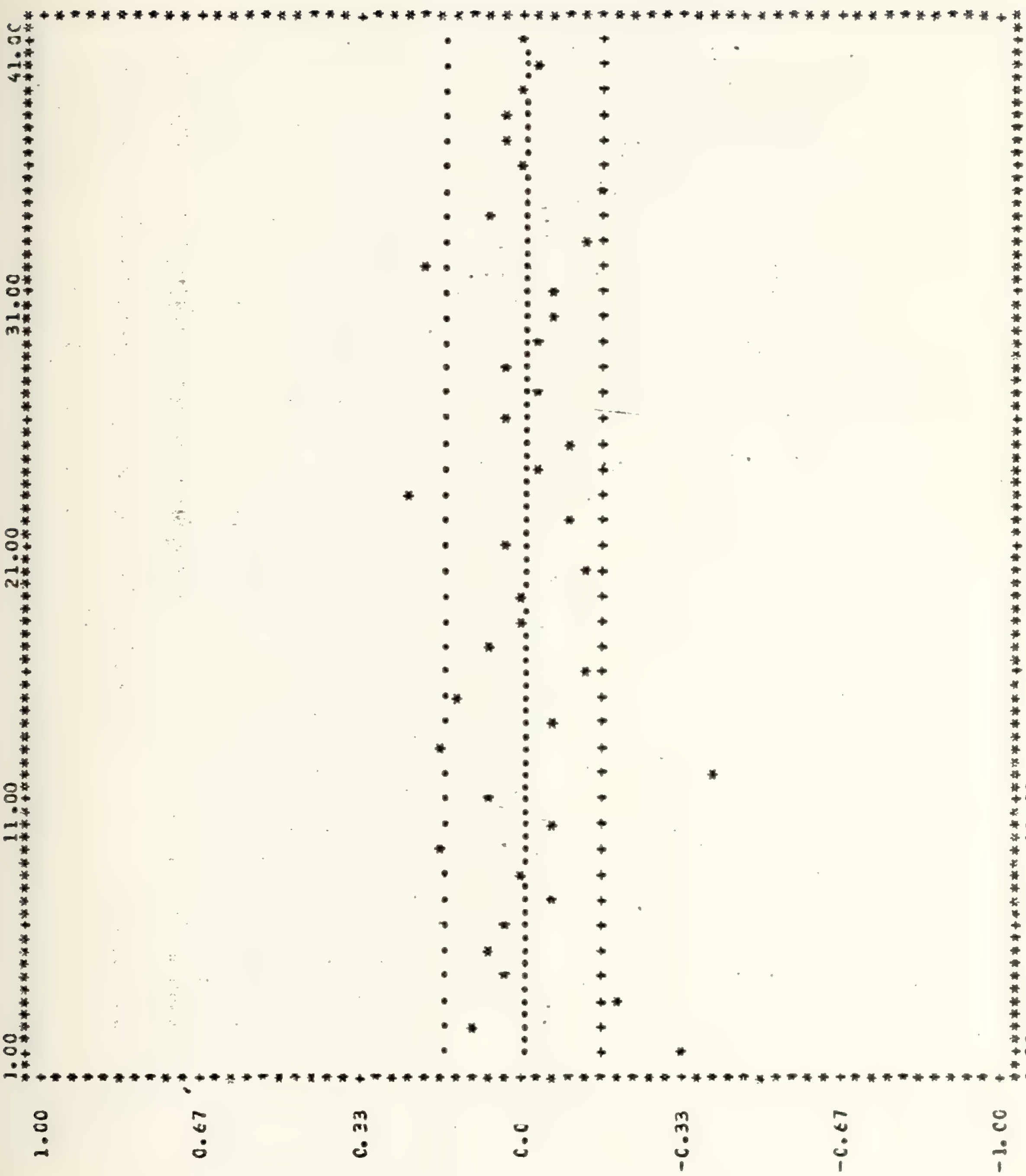
AUTOCORRELATIONS

-0.341	0.105	-0.202	0.021	0.056	0.031	-0.056	-0.001	0.176	-0.076
0.064	-0.387	0.152	-0.058	0.150	-0.139	0.071	0.016	-0.011	-0.117
0.039	-0.091	0.223	-0.018	-0.100	0.049	-0.030	0.047	-0.018	-0.051
-0.054	0.156	-0.122	0.078	-0.152	-0.010	0.047	0.031	-0.015	-0.034

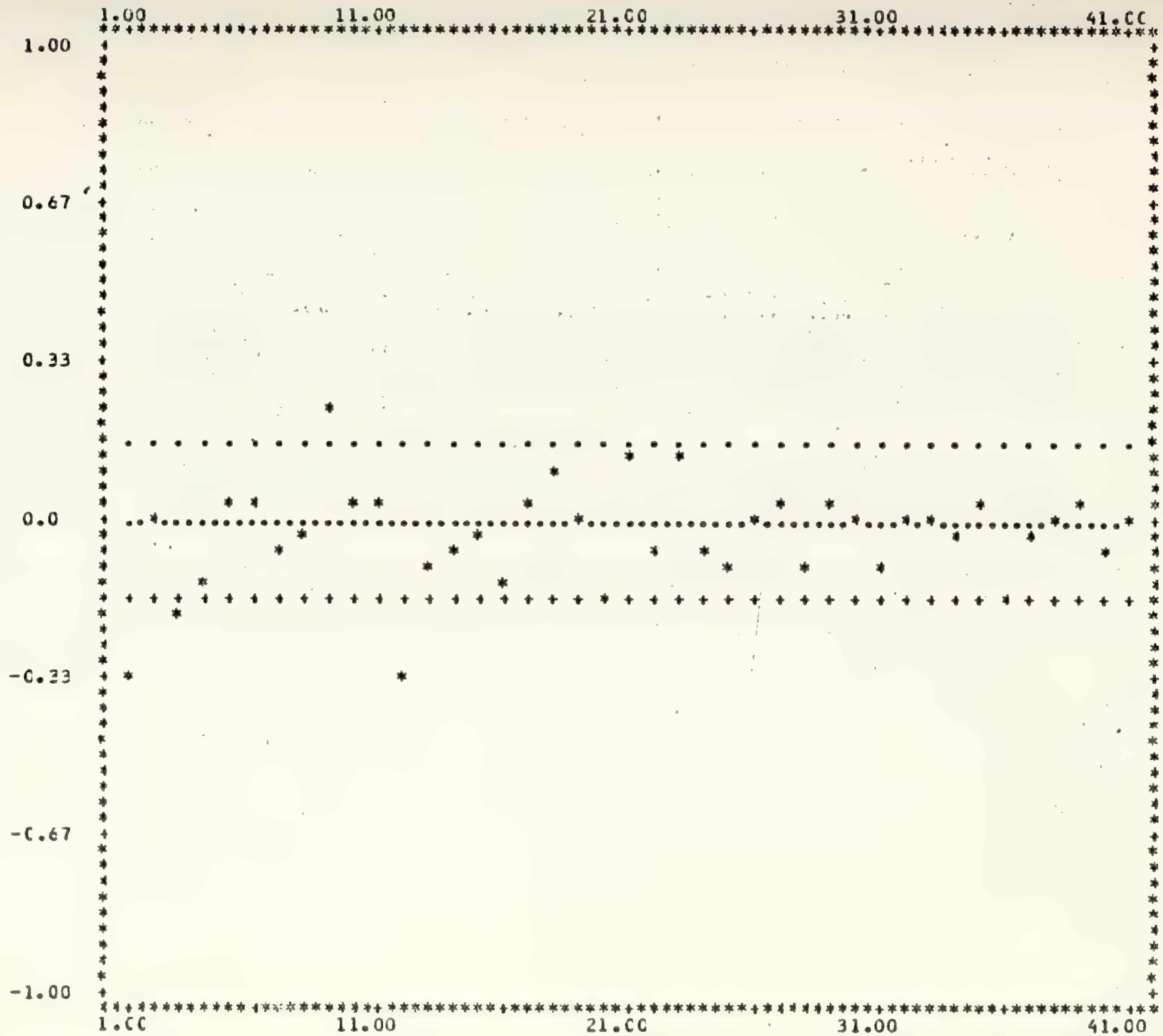
PARTIAL AUTOCORRELATIONS

-0.341	-0.013	-0.193	-0.125	0.033	0.035	-0.060	-0.020	0.226	0.043
0.047	-0.239	-0.109	-0.077	-0.022	-0.140	0.026	0.115	-0.013	-0.167
0.132	-0.072	0.143	-0.067	-0.103	-0.010	0.044	-0.090	0.047	-0.005
-0.096	-0.015	0.011	-0.019	0.023	-0.165	-0.034	0.009	0.045	-0.077

MEAN=0.290920E-03   VARIANCE = 0.208604E-02



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTOS AND PAUTOS FOR SERIES G DATA / 1 NS DIFF, 1 SEAS DIFF,

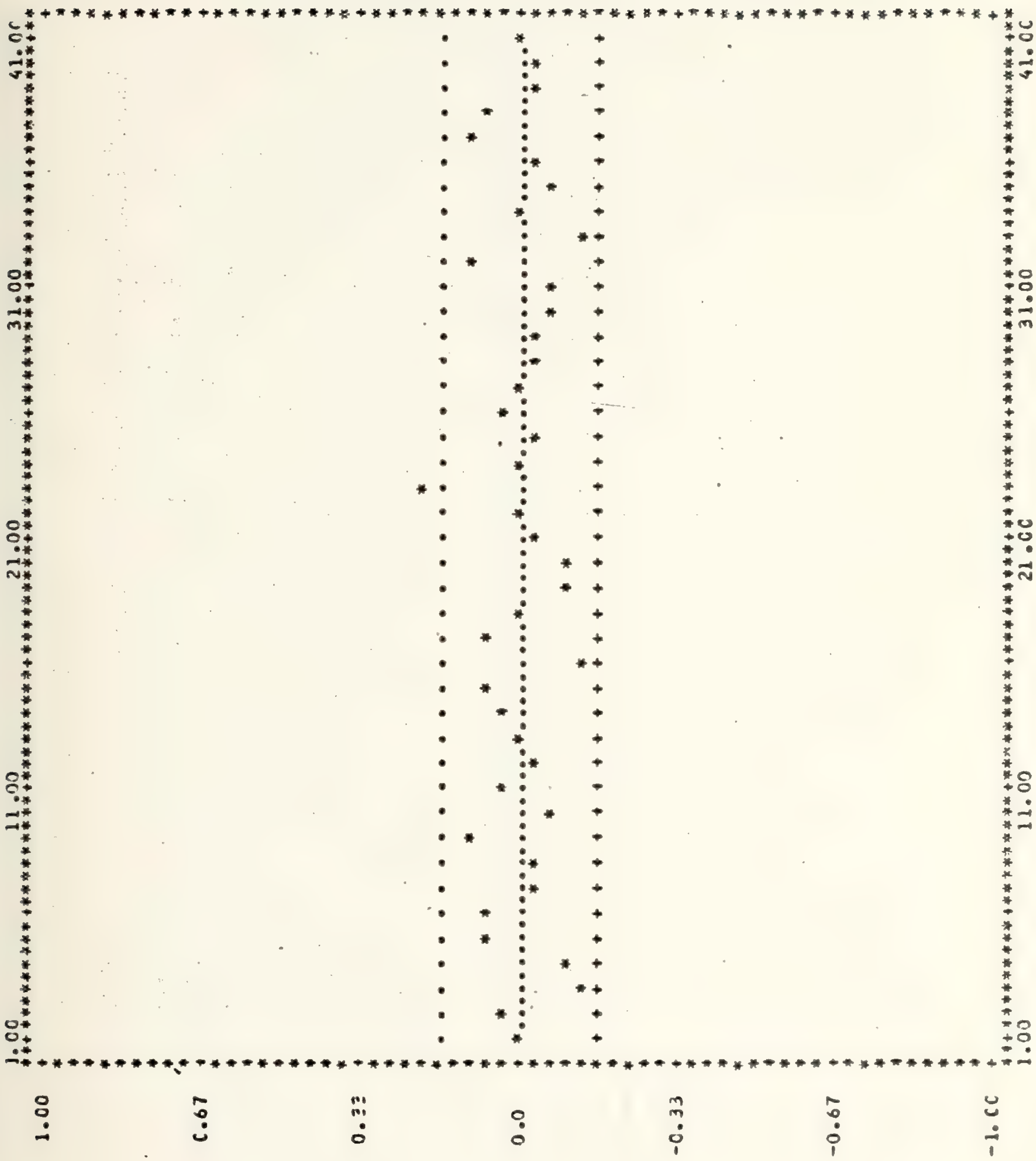
AUTOCORRELATIONS

0.005	0.026	-0.129	-0.105	0.078	0.077	-0.036	-0.033	0.103	-0.050
0.026	-0.020	0.013	0.035	0.067	-0.130	0.052	0.015	-0.093	-0.050
-0.027	-0.014	0.213	0.009	-0.042	0.047	-0.011	-0.032	-0.027	-0.074
-0.063	0.114	-0.142	0.000	-0.081	-0.036	0.089	0.062	-0.024	-0.035

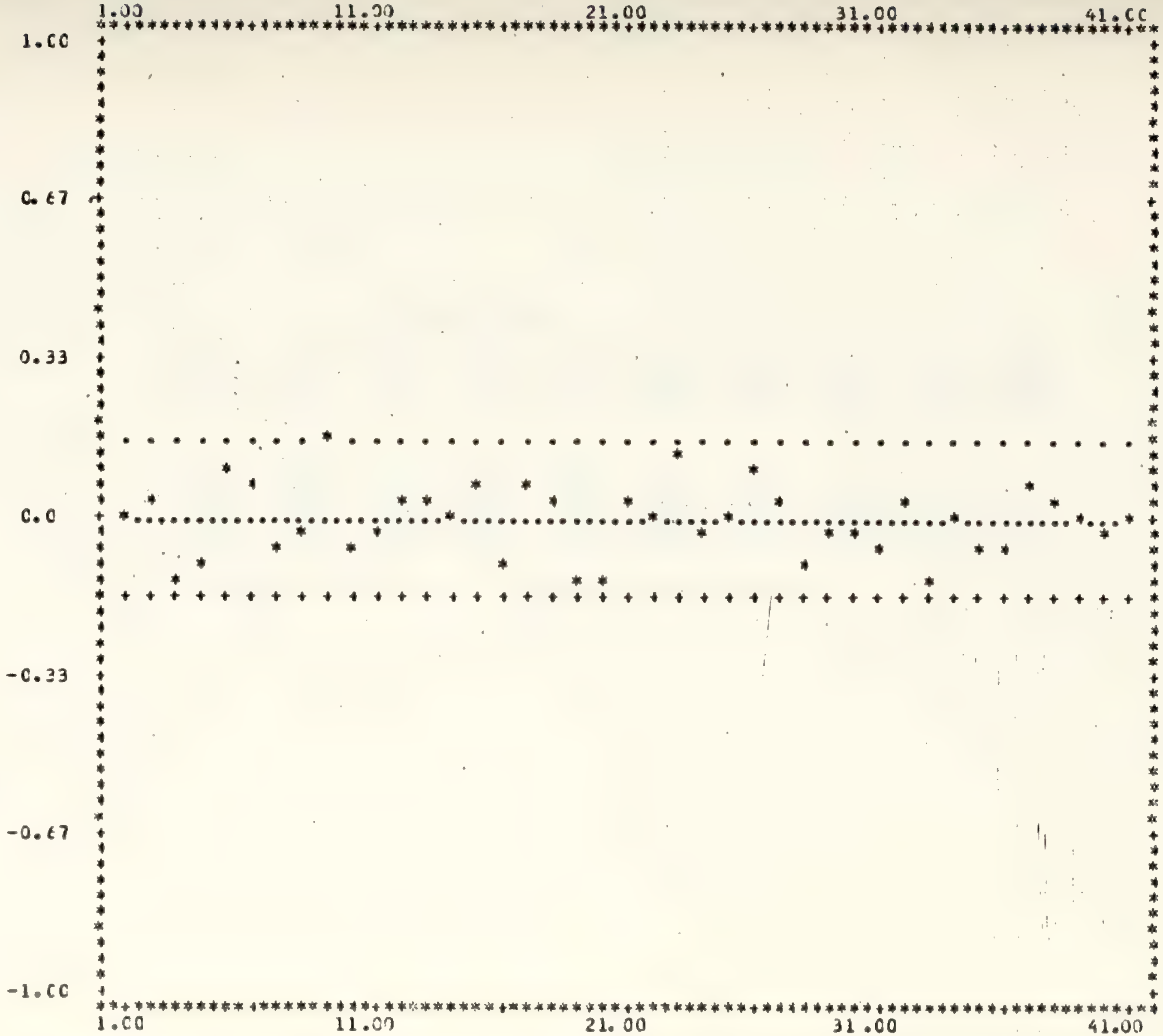
PARTIAL AUTOCORRELATIONS

0.005	0.026	-0.130	-0.104	0.088	0.068	-0.072	-0.029	0.151	-0.057
-0.022	0.018	0.046	0.001	0.053	-0.114	0.069	0.029	-0.129	-0.134
0.042	-0.014	-0.143	-0.025	0.013	0.088	0.024	-0.091	-0.023	-0.033
-0.058	0.025	-0.125	0.008	-0.074	-0.074	0.082	0.041	-0.010	-0.046

MEAN=0.236005E-02 VARIANCE = 0.139713E-02



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTOS AND PAUTCS OF RESIDUALS / (0,1,1)X(0,1,1)12 MODEL OF S

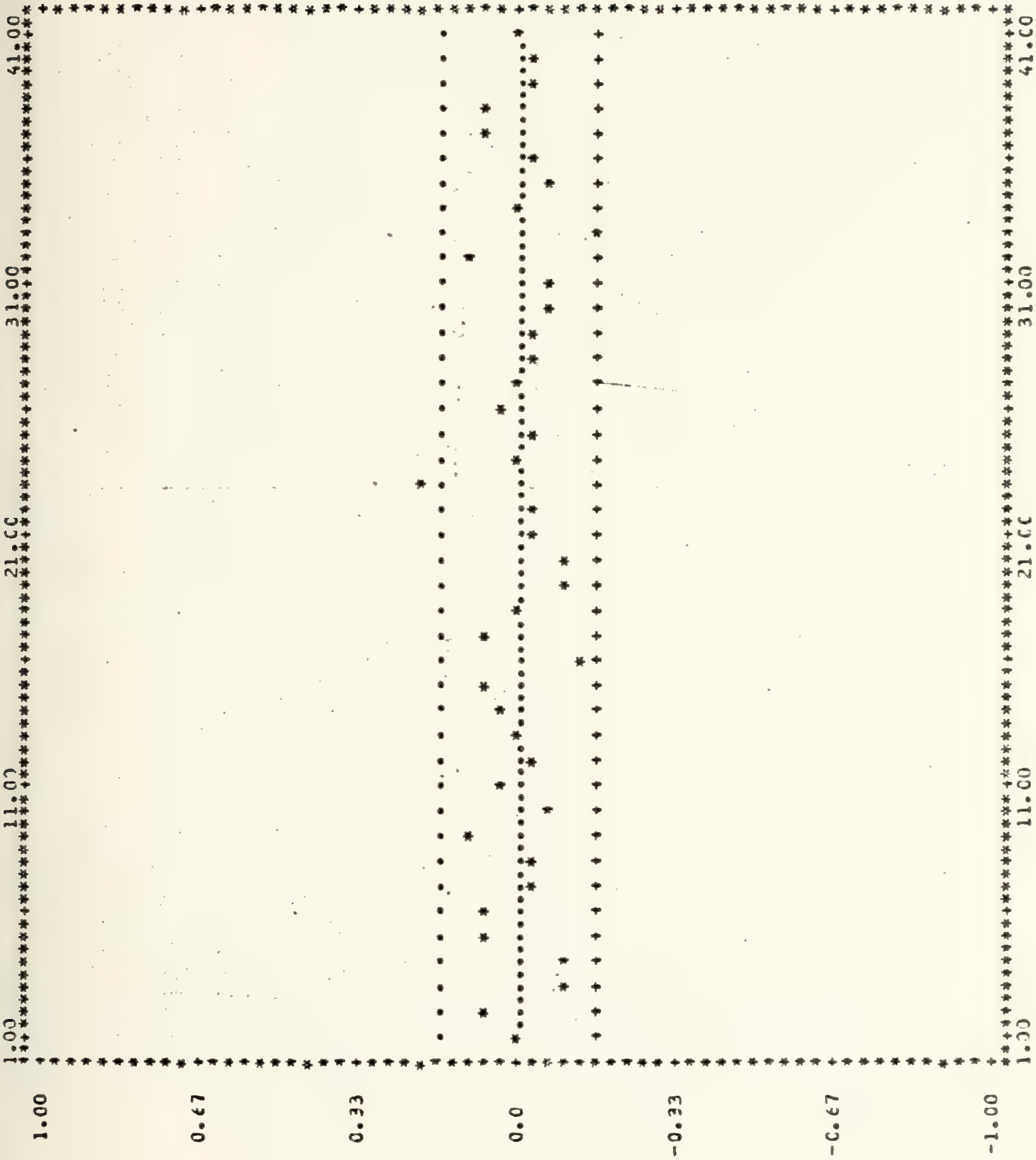
AUTOCORRELATIONS

-0.013	0.073	-0.100	-0.088	0.077	0.073	-0.031	-0.033	0.105	-0.054
0.033	-0.018	0.014	0.027	0.070	-0.133	0.051	0.008	-0.092	-0.084
-0.020	-0.023	0.208	0.005	-0.036	0.048	-0.014	-0.034	-0.027	-0.073
-0.074	0.111	-0.154	0.007	-0.082	-0.037	0.080	0.052	-0.027	-0.032

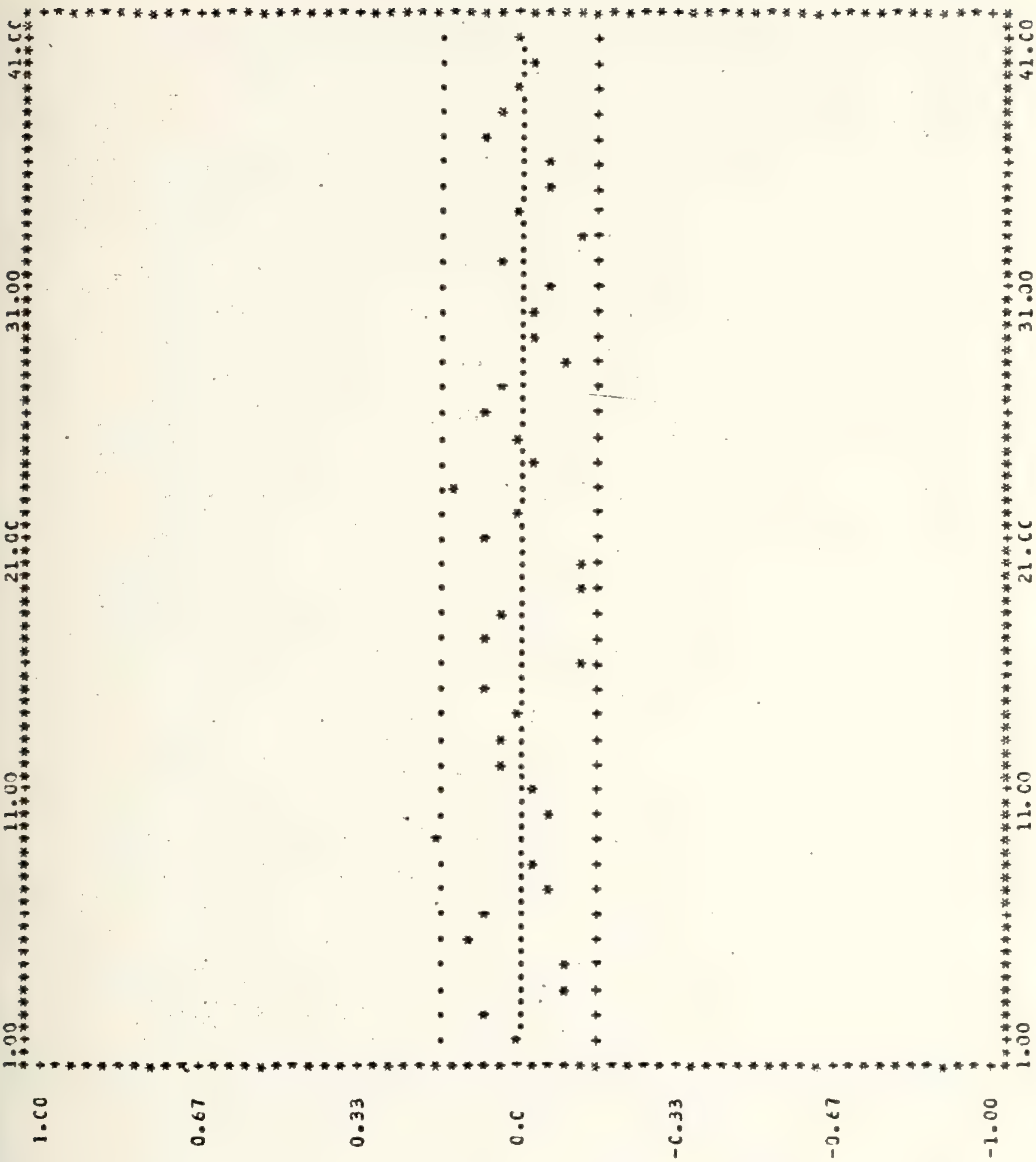
PARTIAL AUTOCORRELATIONS

-0.013	0.073	-0.098	-0.056	0.092	0.081	-0.064	-0.040	0.152	-0.050
-0.027	0.017	0.047	-0.004	0.053	-0.118	0.055	0.031	-0.123	-0.135
0.051	-0.006	0.148	-0.015	0.003	0.079	0.022	-0.059	-0.031	-0.032
-0.063	0.027	-0.130	0.008	-0.062	-0.072	0.082	0.044	-0.012	-0.044

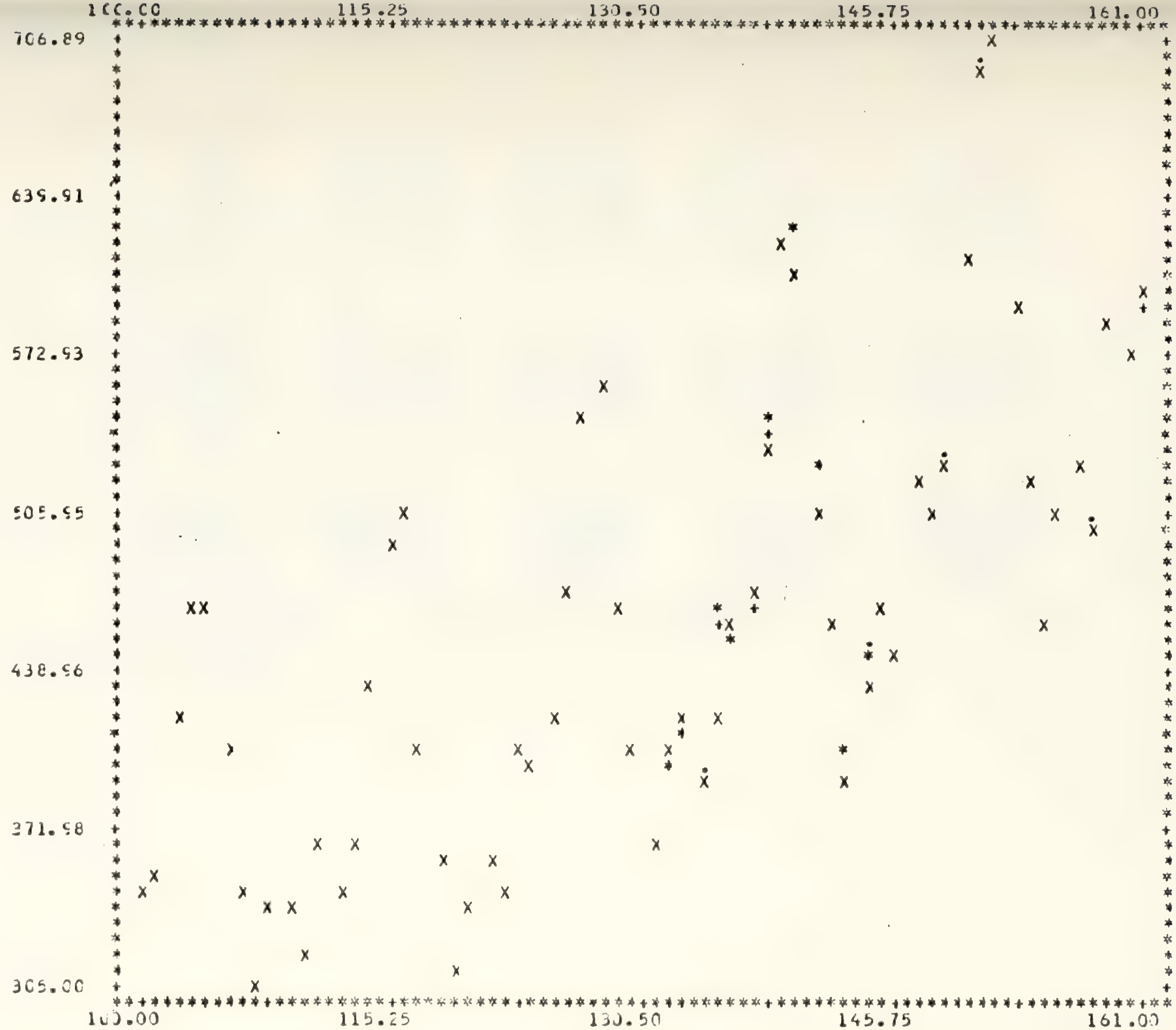
MEAN=0.253052E-02   VARIANCE = 0.139373E-02



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.
AUTOS AND PAUTOS OF RESIDUALS / (1,1,1)X(0,1,1)12 MODEL OF S



ORIGINAL AND FORECASTED TIME SERIES.

. UPPER CONFIDENCE INTERVAL
+ LOWER CONFIDENCE INTERVAL
* FORECASTS
X ACTUAL DATA POINTS

FORECAST VALUES:

398.539063	415.184082	395.401611	462.696533	450.971191
469.709717	543.456055	618.193604	626.275635	524.292480
460.421387	405.212646	448.016357	466.863525	444.748291
520.593018	507.548096	528.791260	611.991455	696.356934
705.666016	590.926758	519.088867	456.978271	505.397217
526.811523	502.002441	587.781982	573.219971	597.385742

UPPER CONFIDENCE LIMITS:

399.598389	416.254395	396.481445	463.784912	452.067627
470.813477	544.566895	619.311035	627.399414	525.422363
461.557129	406.354248	449.173096	468.030273	445.924805
521.779053	508.742920	529.994873	613.203369	697.577148
706.894043	592.162598	520.332275	458.229248	506.663818
528.090088	503.292236	589.083008	574.531738	598.708252

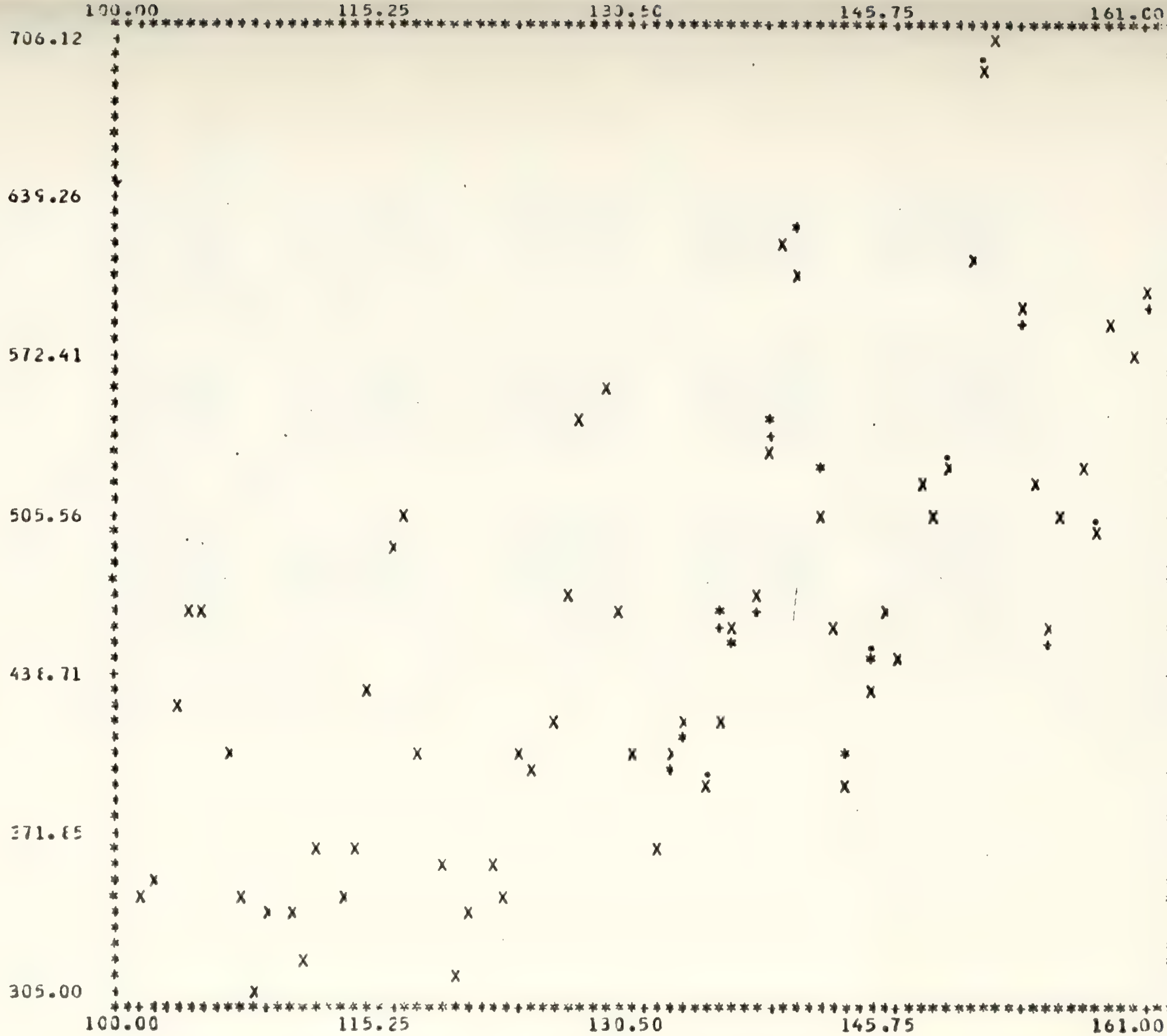
LOWER CONFIDENCE LIMITS:

397.479452	414.113525	394.321533	461.607910	449.874512
468.605713	542.344971	617.075928	625.151611	523.162354
459.285400	404.071045	446.859375	465.696533	443.571533
519.406982	506.353027	527.587402	610.779297	695.136475
704.437744	589.690674	517.845215	455.727051	504.130371
525.532959	500.712402	586.480713	571.907959	596.062988

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST ORIGIN:131

MAXIMUM FORECAST LEAD TIME: 30



ORIGINAL AND FORECASTED TIME SERIES.

- . UPPER CONFIDENCE INTERVAL
- + LOWER CONFIDENCE INTERVAL
- * FORECASTS
- X ACTUAL DATA POINTS

FORECAST VALUES:

398.649658	414.874512	395.124756	462.365723	450.650879
469.348389	543.045166	617.699707	625.752686	523.896729
460.070557	404.899170	447.739258	466.359863	444.324707
520.095703	507.066162	528.257324	611.381348	695.632080
704.905273	590.336426	518.566406	456.512451	504.959717
526.112549	501.399658	587.073975	572.532227	596.632324

UPPER CONFIDENCE LIMITS:

399.708984	415.945068	396.203857	463.452393	451.744385
470.448486	544.151367	618.811768	626.870361	525.019775
461.158730	406.032471	448.886963	467.517334	445.490967
521.270264	508.248779	529.447510	612.579102	696.837158
706.117432	591.555664	519.792236	457.745117	506.207275
527.371094	502.668457	588.352539	573.820557	597.930176

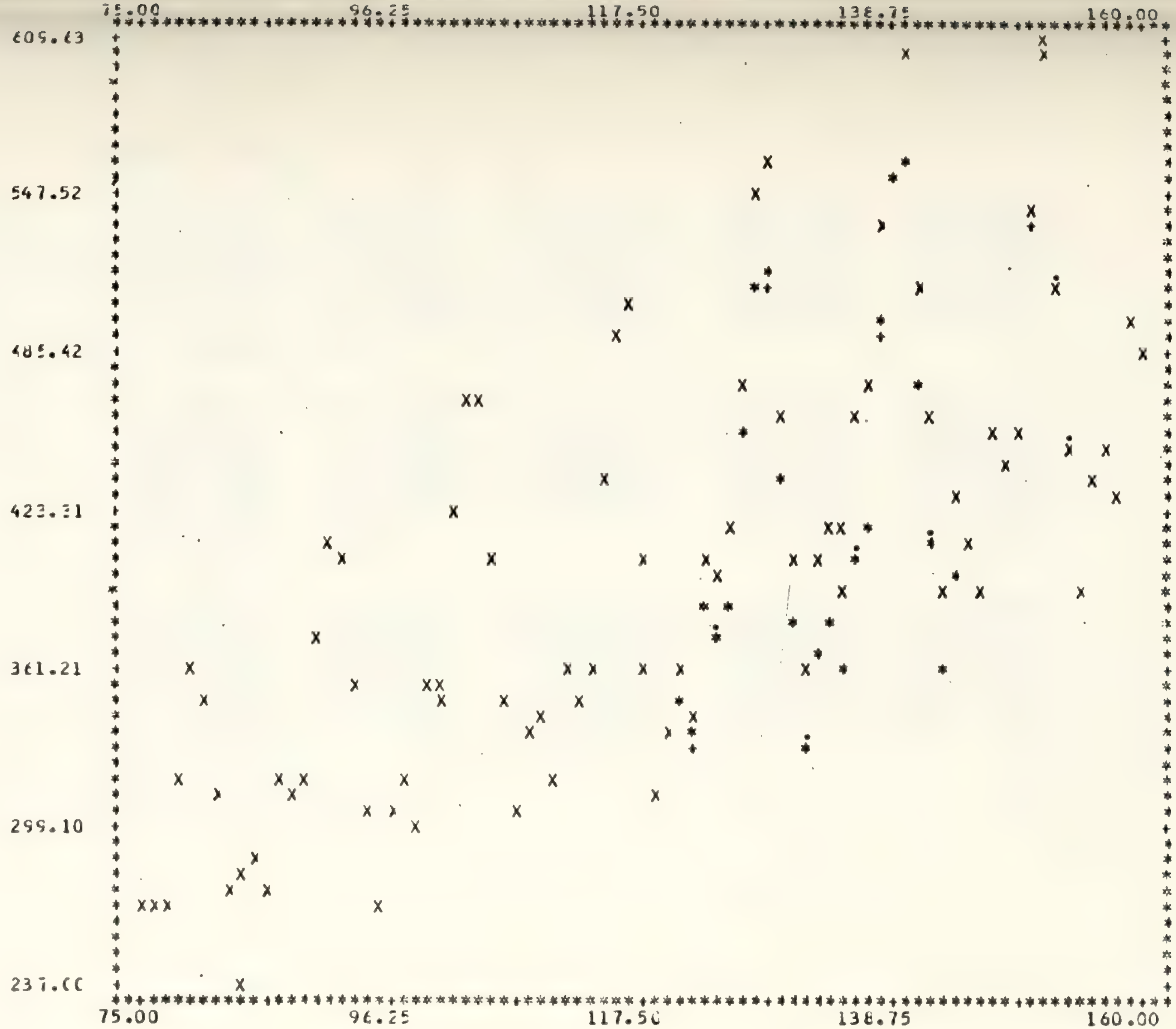
LOWER CONFIDENCE LIMITS:

397.590088	413.803711	394.045410	461.278809	449.557129
468.248047	541.938721	616.587402	624.634766	522.773438
458.942139	403.765625	446.591309	465.202148	443.158203
518.920898	505.883545	527.066895	610.183350	694.426758
703.692871	589.116943	517.340332	455.279541	503.711914
524.853760	500.130615	585.795166	571.243652	595.334229

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST ORIGIN:131

MAXIMUM FORECAST LEAD TIME: 30



NUMBER OF POINTS OUT OF RANGE = 1
ORIGINAL AND FORECASTED TIME SERIES.

. UPPER CONFIDENCE INTERVAL
+ LOWER CONFIDENCE INTERVAL
* FORECASTS
X ACTUAL DATA POINTS

FORECAST VALUES:

349.764404	333.545166	385.947998	375.771729	385.523828
456.098389	510.697754	514.459229	433.913086	380.578125
332.142090	366.207764	378.885010	361.420654	418.324707
407.413086	418.541748	494.791260	554.183838	558.427979
471.135010	413.344971	360.843750	400.142334	411.865479
392.994873	455.002686	443.263184	455.503662	538.643555
403.475342	608.273926	513.338379	450.502686	393.396240
436.366943	449.281982	428.822021	496.626953	483.954346

UPPER CONFIDENCE LIMITS:

350.825195	334.617188	387.030029	376.862549	387.022949
457.205078	511.811523	515.579834	435.040283	381.711670
333.281494	369.353027	380.045898	362.592041	419.506104
408.604248	419.742188	496.000488	555.401855	559.654297
472.369629	414.587646	362.094238	401.400391	413.139893
394.201250	456.301025	444.572998	456.824707	539.975586
604.818115	609.627197	514.701904	451.876465	394.780029
437.760742	450.693848	430.248291	498.067383	485.406447

LOWER CONFIDENCE LIMITS:

348.703369	332.472900	384.865723	374.680664	384.824463
454.991455	509.583740	513.338379	432.785645	379.444336
331.002441	367.062256	377.723877	360.249023	417.143066
406.221680	417.341064	493.581787	552.965576	557.201416
469.900146	412.102051	359.593018	398.884033	410.590820
391.706252	453.704102	441.953125	454.182373	537.311279
602.132324	606.920410	511.974609	449.128662	392.012207
434.972900	447.869873	427.395508	495.186279	482.500000

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST ORIGIN:120

MAXIMUM FORECAST LEAD TIME: 40

APPENDIX D

PROGRAM LISTINGS

This Appendix contains program listings of all programs resident in the Time Series Editor. It does not include listings of subroutines used from other libraries, such as IMSL routines.

```
&TYPEOUT ERROR
CP SET LINELN 80
GLOBAL T SLBS SYSLIB IMSLSF SSPLIB
CLOSIO PRINTER OFF
VSET BLIP *
&KXY = &1
&IF &KXY EQ S &GOTO -ST2
&UPRINT EACH 2 SECONDS EXECUTION TIME IS INDICATED BY *.
&SPACE 1
&PRINT YOU HAVE ENTERED THE TIME SERIES EDITOR.
&SPACE 1
&UPRINT PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.
&UPRINT ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.
&UPRINT ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.
&SPACE 1
&UPRINT TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING
&UPRINT WITH I THRU N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.
&SPACE 1
-ST &PRINT DO YOU WANT A LIST OF THE OPTIONS?
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ Y &GOTO -PRINTX
-ST2 &SPACE 1
&PRINT ENTER LETTER FOR OPTION YOU WANT.
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ H &GOTO -NIT
&IF &1 EQ C &GOTO -LOAD14
&IF &1 EQ G &GOTO -LOAD1
&IF &1 EQ R &GOTO -LOAD8
&IF &1 EQ S &GOTO -LOAD10
&OPTION = &1
&IF &1 EQ A &GOTO -MESS
&IF &1 EQ P &GOTO -MESS
&IF &1 EQ D &GOTO -MESS
&IF &1 EQ E &GOTO -MESS
&IF &1 EQ F &GOTO -MESS
&IF &1 EQ T &GOTO -MESS
&IF &1 EQ X &GOTO -MESS
&IF &1 EQ Y &GOTO -MESS
&IF &1 EQ W &GOTO -MESS
&IF &1 EQ Z &GOTO -MES1
-RUSS &SPACE 1
&PRINT ILLEGAL OPTION. CHECK VALID OPTIONS.
&GOTO -QUES
-MES1 &CONTINUE
&UPRINT IS YOUR DATA IN FILE FT03F001?
&GOTO -LBL1
-MESS &CONTINUE
&IF &KXY EQ S &GOTO -CHECK
&UPRINT IS YOUR DATA IN FILE FT02F001?
-LBL1 &READ ARGS
&ERROR &CONTINUE
&IF &1 EQ Y &GOTO -CHECK
&UPRINT HAVE YOU ALREADY SUBMITTED YOUR DATA TO BE READ OFFLINE INTO CP/CMS?
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ N &GOTO -ENTER
C READ *
-CHECK &IF &OPTION EQ A &GOTO -LOAD2
&IF &OPTION EQ P &GOTO -LOAD3
&IF &OPTION EQ D &GOTO -LOAD4
&IF &OPTION EQ E &GOTO -LOAD5
&IF &OPTION EQ F &GOTO -LOAD6
&IF &OPTION EQ T &GOTO -LOAD7
&IF &OPTION EQ Z &GOTO -LOAD9
&IF &OPTION EQ W &GOTO -LOAD11
&IF &OPTION EQ X &GOTO -LOAD12
&IF &OPTION EQ Y &GOTO -LOAD13
-LOAD1 LOAD GENERATE (CLEAR XEQ NOMAP)
```

```
C PRINT FILE FT01F001
&GOTO -QUES
-LOAD11 LOAD WHARQROT (CLEAR NOMAP LIBE) SUBS SYSLIB IMSLDP
START *
&GOTO -MESS2
-LOAD2 LOAD AUTO (CLEAR XEQ NOMAP)
C PRINTCC FILE FT08F001
&GOTO -QUES
-LOAD3 LOAD PLOT (CLEAR XEQ NOMAP)
C PRINTCC FILE FT08F001
&GOTO -QUES
-LOAD4 LOAD DIFF (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 P1 FILE FT09F001 P1
ALTER FILE FT03F001 P1 FILE FT02F001 P1
LOAD AUTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 P1 FILE FT03F001 P1
ALTER FILE FT09F001 P1 FILE FT02F001 P1
&SPACE 1
&GOTO -QUES
-LOAD5 LOAD ESTIMATE (CLEAR XEQ NOMAP)
-MESS2 &CONTINUE
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 P1 FILE FT09F001 P1
ALTER FILE FT03F001 P1 FILE FT02F001 P1
LOAD AUTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 P1 FILE FT03F001 P1
ALTER FILE FT09F001 P1 FILE FT02F001 P1
&SPACE 1
&GOTO -QUES
-LOAD6 LOAD FORECAST (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
&SPACE 1
&GOTO -QUES
-LOAD7 LOAD TRANS (CLEAR XEQ NOMAP)
ALTER FILE FT02F001 P1 DATA FT02F001 P1
ALTER FILE FT03F001 P1 FILE FT02F001 P1
&UPRINT YOUR ORIGINAL SERIES IS IN DATA FT02F001 P1.
&UPRINT YOUR TRANSFORMED SERIES IS IN FILE FT02F001 P1.
&SPACE
&UPRINT DO YOU WANT TO PLOT THE TRANSFORMED VALUES?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
LOAD PLOT (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
&SPACE 1
&GOTO -QUES
-LOAD8 LOAD ROOTS (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -QUES
-LOAD9 LOAD ZFORMAT (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -QUES
-LOAD12 LOAD XSUMSC (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -QUES
-LOAD13 LOAD YESTSEAS (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -QUES
-LOAD14 &CONTINUE
&UPRINT ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.
&UPRINT WHEN FINISHED TYPE: &GOTO -QUES
```

```
&READ 20
&GOTO -QUES
-LOAD10 LOAD SIMULATE (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -QUES
-QUES &PRINT DO YOU WANT TO GO AGAIN?
&READ ARGS
&ERROR &GOTO -QUES
&IF &1 EQ N &GOTO -END
&GOTO -ST2
-PRINTX &CONTINUE
PRINTF TSERIES PARA 1 15
-NOWS &SPACE 1
&PRINT WOULD YOU LIKE MORE INFO?
&READ ARGS
&ERROR &CONTINUE
&IF &1 NE Y &GOTO -ST2
&SPACE 1
-NIT &PRINT ENTER OPTION YOU WANT INFO ABOUT.
&READ ARGS
&ERROR &GOTO -NOWS
&IF &1 EQ P &GOTO -XP
&IF &1 EQ D &GOTO -XD
&IF &1 EQ E &GOTO -XE
&IF &1 EQ A &GOTO -XA
&IF &1 EQ F &GOTO -XF
&IF &1 EQ T &GOTO -XT
&IF &1 EQ G &GOTO -XG
&IF &1 EQ R &GOTO -XR
&IF &1 EQ S &GOTO -XS
&IF &1 EQ X &GOTO -XX
&IF &1 EQ Y &GOTO -XY
&IF &1 EQ W &GOTO -XW
&IF &1 EQ C &GOTO -XC
&IF &1 EQ Z &GOTO -XZ
&UPRINT ILLEGAL NAME. ENTER FIRST LETTER ONLY. CHECK OPTIONS.
&GOTO -NIT
-XP PRINTF TSERIES PARA 48 49
&GOTO -LEE
-XD PRINTF TSERIES PARA 50 53
&GOTO -LEE
-XE PRINTF TSERIES PARA 57 60
&GOTO -LEE
-XA PRINTF TSERIES PARA 43 47
&GOTO -LEE
-XF PRINTF TSERIES PARA 32 35
&GOTO -LEE
-XT PRINTF TSERIES PARA 28 31
&GOTO -LEE
-XG PRINTF TSERIES PARA 36 42
&GOTO -LEE
-XR PRINTF TSERIES PARA 61 63
&GOTO -LEE
-XS PRINTF TSERIES PARA 82 85
&GOTO -LEE
-XX PRINTF TSERIES PARA 71 72
&GOTO -LEE
-XY PRINTF TSERIES PARA 68 70
&GOTO -LEE
-XW PRINTF TSERIES PARA 77 81
&GOTO -LEE
-XC PRINTF TSERIES PARA 73 76
&GOTO -LEE
-XZ PRINTF TSERIES PARA 64 67
&GOTO -LEE
-LEE &SPACE 1
&UPRINT DO YOU WANT INFO ABOUT ANOTHER OPTION?
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ Y &GOTO -NIT
```

```
&PRINT DC YCU WANT TO TRY A SESSION?
&READ ARGS
&ERROR &GCTC -END
&IF &1 EC N &GCTC -END
&GCTC -ST2
-ENTER &CONTINUE
&FPINT DO YOL WANT INFO ON HOW TC ENTER YOLR SERIES?
&READ ARGS
&ERRCR &CCNTINUE
&IF &1 EC Y &GCTC -HCW
&FPINT ENTER SERIES OFFLINE AND RETURN.
&GCTO -END
-HCW PRINTF TSERIES PARA 17 27
-END &PRINT CCNTRCL RETURNED TO CMS
CLCSIC PRINTER ON
&EXIT
```

```
OPTION                    DESCRIPTION                                           TIM02020
GENERATE -----GENERATE ANY ARIMA TIME SERIES                                    TIM02030
AUTO ---------CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT ---------PLOT A TIME SERIES                                                TIM02050
ESTIMATE -----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS             TIM02070
DIFF ---------DIFFERENCE A TIME SERIES
FORECAST -----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
TRANS --------TRANSFORMS VALUES OF A TIME SERIES
ROOTS --------DETERMINES ROOTS OF ARIMA CHARACTERISTIC EQUATION
ZFORMAT ------ALTER DATA FILE TO FORMAT 5F15.6
CMSWORK ------PERFORM CP/CMS COMMANDS IN TIMESER EXEC
SIMULATE -----SIMULATE NONSEASONAL TIME SERIES
YESTSEAS -----CALCULATE INITIAL SEASONAL PARAMETERS
WMARQRDT -----MARQUARDT SOLUTION FOR PARAMETER ESTIMATES
XSUMSQ -------CALCULATE SUM OF SQUARES FOR ARBITRARY PARAMETERS
HELP ---------ASK FOR PROGRAM INFO AFTER INITIAL INTRODUCTION
THE FIRST TWO CARDS ARE OFFLINE READ CONTROL CARDS:
CP67USERID  XXXXG   (WHERE XXXX IS USER ID NO.)
OFFLINE READ FILE FT02F001 (FT03F001 IF OPTION IS ZFORMAT)
THESE TWO CARDS ARE THEN FOLLOWED BY THE DATA CARDS:
XXX     (WHERE XXX IS THE LENGTH OF THE TIME SERIES)
(NOW ENTER THE TIME SERIES DATA VIA FORMAT (5F15.6))
(IF YOUR DATA ARE IN A DIFFERENT FORMAT, USE RFORMAT TO REWRITE
IT INTO THE REQUIRED FORMAT.)
(USE AS MANY CARDS AS NECESSARY TO ENTER THE TIME SERIES)
SUBMIT THIS DECK TO THE OPERATOR TO BE READ INTO
CP/CMS, THEN RETURN FOR ANOTHER SESSION.
TRANS --------THIS PROGRAM WILL TRANSFORM THE VALUES OF A TIME SERIES
WITH A CHANGE OF ORIGIN, A CHANGE OF SCALE, A POWER OR ROOT TRANS-
FORMATION, OR A LOGARITHMIC TRANSFORMATION.  THE ORIGINAL SERIES IS
SWITCHED TO THE FILE DATA FT02F001 P1; NEW DATA IS IN FILE FT02F001.
FORECAST -----THIS PROGRAM TAKES A GIVEN ARIMA MODEL WITH PARA-
METERS THAT HAVE ALREADY BEEN ESTIMATED AND CALCULATES FORECASTS
OF FUTURE VALUES.  IT ALSO DETERMINES CONFIDENCE LIMITS FOR THE
VALUES THAT HAVE BEEN FORECASTED.
GENERATE ----THIS PROGRAM GENERATES A TIME SERIES SPECIFIED BY THE USER.MO2120
IT CAN HANDLE ANY ARIMA MODEL WITH NUMBER OF AR TERMS AT MOST 6 AND NUM.TIM02130
OF MA TERMS AT MOST 6.  THE TIME SERIES CAN BE STATIONARY OR HOMOGENEOUSTIM02140
NONSTATIONARY.  THE PROGRAM USES FTGEN1 FROM THE IMSL LIBRARY. THE USER TIM02150
SPECIFIES ALL PARAMETERS AND STARTING CONDITIONS.  THE PROGRAM TAKES THETIM02160
GIVEN MODEL, GENERATES RANDOM NOISE TERMS AND CALCULATES AS MANY VALUES TIM02170
AS REQUESTED.                                                               TIM02
AUTO --------THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL
AUTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES
WHICH MUST RESIDE IN FILE FT02F001.  THE PROGRAM USES
FTAUTO IN THE IMSL LIBRARY.  THE AUTOCORRELATIONS AND PAUTOS CAN BE       S
PLOTTED OFFLINE.
PLOT --------THIS PROGRAM PLOTS A GIVEN TIME SERIES WHICH RESIDES IN
FILE FT02F001.  IT USES THE PLOTP PROGRAM IN THE IBM SSPLIB.
DIFF --------THIS PROGRAM TAKES A SERIES IN FILE FT02F001, ASKS IF
IT IS SEASONAL, AND THEN PERFORMS NONSEASONAL AND/OR SEASONAL
DIFFERENCING, AS REQUESTED.  THE ORIGINAL DATA REMAINS IN FILE
FT02F001, WHILE THE DIFFERENCED SERIES IS PUT IN FILE FT03F001.


ESTIMATE ----THIS PROGRAM CALCULATES MAXIMUM LIKELIHOOD ESTIMATES OF THE
AUTOREGRESSIVE AND THE MOVING AVERAGE PARAMETERS OF AN ARMA MODEL.
IT ALSO DETERMINES THE RESIDUALS WHICH CAN BE USED TO CHECK OUT THE
MODEL. IT USES THE PROGRAM FTMAXL FROM THE IMSL LIBRARY.
ROOTS -------THIS PROGRAM DETERMINES THE ROOTS OF THE CHARACTERISTIC
EQUATION OF A GIVEN ARIMA MODEL.  THE ROOTS ARE USEFUL FOR TESTING
FOR STATIONARITY AND FOR DETERMINING THE FORM OF THE FORECAST FCT.
ZFORMAT -----THIS PROGRAM TAKES A DATA FILE IN ANY FORTRAN FORMAT
LOADED IN FILE FT03F001, AND TRANSFORMS IT INTO THE PROPER FORMAT
FOR THE TIME SERIES EDITOR, WRITING IT INTO FILE FT02F001.  THE
ORIGINAL DATA REMAINS IN FILE FT03F001.
YESTSEAS ----THIS PROGRAM CALCULATES INITIAL PARAMETER ESTIMATES
FOR SEASONAL AND NONSEASONAL ARIMA MODELS, TO BE USED AS INPUTS TO
THE WMARQRDT PROGRAM.
```

```
XSUMSQ ------THIS PROGRAM CALCULATES THE SUM OF SQUARED RESIDUALS
FOR ANY SET OF ARIMA (SEASONAL OR NONSEASONAL) PARAMETERS.
CMSWORK -----THIS PROGRAM ALLOWS THE USER TO EXECUTE CP/CMS
COMMANDS WHILE REMAINING IN THE TIMESER EXEC ENVIRONMENT; THIS
INCLUDES ALTER, ERASE, CP C F, OFFLINE READ, OFFLINE PUNCH,
OFFLINE PRINT, STAT, LISTF, ETC.
WMARQRCT ----THIS PROGRAM CALCULATES NON-LINEAR LEAST SQUARES
ESTIMATES OF BOX-JENKINS PARAMETERS FOR A GENERAL (SEASONAL
OR NONSEASONAL) ARIMA MODEL.  IT REQUIRES INITIAL PARAMETER
ESTIMATES AS STARTING VALUES; THESE MAY BE CALCULATED USING
PROGRAM YESTSEAS.
SIMULATE ----THIS PROGRAM SIMULATES ANY NON-SEASONAL ARIMA
TIME SERIES, GIVEN THE MODEL PARAMETERS. IT WILL WORK
WITH THE ACTUAL DATA, OR WITH INITIAL VALUES ENTERED ON THE
TERMINAL. IT USES PART OF THE GENERATE PROGRAM.
```

```
C
C        THE ROUTINE ZFMT TAKES TIME SERIES DATA IN ANY FORTRAN
C        FORMAT AND REWRITES IT IN THE FORMAT SUITABLE FOR
C        ANALYSIS IN THE TIME SERIES EDITOR.
C
C        THE SERIES IS ENTERED ONTO THE DISC IN FILE FT03F001,
C        AND IS REWRITTEN BY THIS PROGRAM ONTO FILE FT02F001
C        IN FORMAT 5F15.6, REQUIRED FOR USE IN TIME SERIES EDITOR
C        PROGRAMS. THE ORIGINAL DATA IS NOT DESTROYED, BUT
C        REMAINS IN FILE FT03F001.
C
      DIMENSION DATA(1000),FMT(18)
      DATA Y/'Y'/,FMT/18*'    '/
      WRITE(6,10)
   10 FORMAT(/,2X,'IS YOUR TIME SERIES DATA NOW IN FILE FT03F001?')
      READ(5,11)ANS
   11 FORMAT(A1)
      IF(ANS.NE.Y)GO TO 99
      WRITE(6,12)
   12 FORMAT(/,2X,'ENTER THE LENGTH OF YOUR TIME SERIES VIA FORMAT I3.')
      READ(5,13)N
   13 FORMAT(I3)
   20 WRITE(6,14)
   14 FORMAT(/,2X,'NOW ENTER THE FORTRAN FORMAT FOR YOUR TIME SERIES DAT
     1A,',/,2X,'INCLUDING PARENTHESES; FOR EXAMPLE, TYPE: (5F15.7).')
      READ(5,15)FMT
   15 FORMAT(18A4)
      WRITE(6,21)FMT
   21 FORMAT(/,2X,'YOUR FORMAT IS:',/,2X,'FORMAT',18A4,/,2X,'IS THIS COR
     1RECT?')
      READ(5,19)ANS
   19 FORMAT(A1)
      IF(ANS.NE.Y)GO TO 20
      WRITE(6,16)
   16 FORMAT(/,2X,'YOUR DATA IS NOW TRANSFORMED INTO THE PROPER FORMAT',
     1/,2X,'FOR USE IN THE TIME SERIES EDITOR,LOCATED IN FILE',/,2X,
     2'FT02F001. YOUR ORIGINAL DATA IS IN FILE FT03F001.')
      WRITE(2,13)N
      READ(3,FMT)(DATA(I),I=1,N)
      WRITE(2,18)(DATA(I),I=1,N)
   18 FORMAT(5F15.6)
      GO TO 97
   99 WRITE(6,98)
   98 FORMAT(/,2X,'LOAD YOUR DATA AS FILE FT03F001 ONTO YOUR DISC,',/,2X
     1,'IN ACCORDANCE WITH INSTRUCTIONS IN THE USER GUIDE.')
   97 STOP
      END
```

```
      DIMENSION X(1000),Z(1000),TITLE(60)
      DATA Y/'Y'/
      READ(2,200)N
200   FORMAT(I3)
      READ(2,201)(Z(I),I=1,N)
201   FORMAT(5E15.6)
      DO 10 I=1,N
10    X(I)=I
9     FORMAT('1')
      WRITE(8,9)
      CALL PLOT8(X,Z,N,0)
      WRITE(6,63)
      READ(5,53)TITLE
63    FORMAT(2X,'ENTER TITLE FOR PLOT')
53    FORMAT(60A1)
      WRITE(8,81)TITLE
81    FORMAT(15X,60A1)
      WRITE(6,64)
64    FORMAT(2X,'TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE')
      STOP
      END
```

```
      DIMENSION W(1000),ACV(50),PACV(50),WKAREA(50)
      DIMENSION BU(50),BL(50)
      DIMENSION RANGE(4),T(50),AC(50),TITLE(60)
      DATA Y/'Y'/
      READ(2,307)LW
  307 FORMAT(I3)
      READ(2,802)  (W(I),I=1,LW)
  802 FORMAT(5E15.6)
      CALL FTAUTO(W,LW,40,40,7,AMEAN,VAR,ACV,AC,PACV,WKAREA)
    4 FORMAT(//5X,'MEAN=',G12.6,5X,'VARIANCE = ',G12.6,/)
      WRITE(6,5)
      WRITE(8,5)
    5 FORMAT(15X,'AUTOCORRELATIONS',/)
      WRITE(6,6)  (AC(I),I=1,25)
      WRITE(8,6)  (AC(I),I=1,40)
    6 FORMAT(10F7.3)
      WRITE(6,7)
      WRITE(8,7)
    7 FORMAT(//10X,'PARTIAL AUTOCORRELATIONS',/)
      WRITE(6,6)  (PACV(I),I=1,25)
      WRITE(8,6)  (PACV(I),I=1,40)
      WRITE(8,4)  AMEAN,VAR
      WRITE(6,4)  AMEAN,VAR
      RANGE(1)=41
      RANGE(2)=1
      RANGE(3)=1.0
      RANGE(4)=-1.0
      DO 8 I=1,41
      XLW=LW
      BU(I)=2.0/SQRT(XLW)
      BL(I)=-BU(I)
    8 T(I)=I
      WRITE(8,9)
    9 FORMAT('1')
      CALL UTPLT8(T,BL,41,RANGE,1,1)
      CALL UTPLT8(T,BL,41,RANGE,1,2)
      CALL UTPLT8(T,AC,41,RANGE,1,3)
      WRITE(8,10)
   10 FORMAT(15X,'AUTOCORRELATIONS WITH 2 SIGMA BANDS.')
      WRITE(8,9)
      CALL UTPLT8(T,BU,41,RANGE,1,1)
      CALL UTPLT8(T,BL,41,RANGE,1,2)
      CALL UTPLT8(T,PACV,41,RANGE,1,3)
      WRITE(8,11)
   11 FORMAT(10X,'PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.')
      WRITE(6,61)
   61 FORMAT(2X,'ENTER TITLE FOR PLOTS.')
      READ(5,51) TITLE
   51 FORMAT(60A1)
      WRITE(8,62) TITLE
   62 FORMAT(15X,65A1)
      WRITE(6,15)
   15 FORMAT('  YOUR AUTC AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.'/
     *'  PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.')
      STOP
      END
```

```
      DIMENSION  Z(999)
      DATA  Y/'Y'/,IS/1/,ID1/0/,ID2/0/
      READ(2,200)  LZ
  200 FORMAT(I3)
      READ(2,201)  (Z(I),I=1,LZ)
  201 FORMAT(5E15.6)
      WRITE(6,609)
  609 FORMAT(2X,'IS YOUR TIME SERIES SEASONAL?')
      READ(5,502) ANS
  502 FORMAT(A1)
      IF(ANS.NE.Y) GO TO 1000
   20 WRITE(6,601)
  601 FORMAT(2X,'ENTER ORDER OF SEASONAL DIFFERENCING.')
      READ(5,503) ID2
  503 FORMAT(I1)
   10 WRITE(6,604)
  604 FORMAT(2X,'ENTER LENGTH OF SEASONAL PERIOD VIA I2.')
      READ(5,504) IS
  504 FORMAT(I2)
 1000 WRITE(6,600)
  600 FORMAT(2X,'ENTER NUMBER OF NONSEASONAL DIFFERENCES.')
      READ(5,503) ID1
   50 CALL FTRDIF(ID1,ID2,1,IS,LZ,Z,SHIFT,M,IER)
  925 WRITE(3,60) M
   60 FORMAT(I3)
      WRITE(3,61) (Z(I),I=1,M)
   61 FORMAT(5E15.6)
      IF(IER.EQ.0) GO TO 70
      WRITE(6,608) IER
  603 FORMAT(2X,'ERROR PARAMETER =',I3)
   70 STOP
      END
```

```
      DIMENSION Z(999)
      DATA Y/'Y'/,SHIFT/0./,SCALE,P/2*1./,L/0/
      READ(2,400) LZ
      READ(2,21) (Z(I),I=1,LZ)
  400 FORMAT(I3)
   21 FORMAT(5E15.6)
      WRITE(6,1)
    1 FORMAT(2X,'DO YOU WANT TO TRANSLATE THE ORIGIN: W=Z-SHIFT?')
      READ(5,2) ANS
    2 FORMAT(A1)
      IF(ANS.NE.Y) GO TO 5
      WRITE(6,3)
    3 FORMAT(2X,'ENTER VALUE FOR SHIFT.')
      READ(5,4) SHIFT
    4 FORMAT(F10.2)
    5 WRITE(6,6)
    6 FORMAT(2X,'DO YOU WANT TO RESCALE THE VALUES: W=Z*SCALE?')
      READ(5,2) ANS
      IF(ANS.NE.Y) GO TO 8
      WRITE(6,7)
    7 FORMAT(2X,'ENTER VALUE FOR SCALE.')
      READ(5,4) SCALE
    8 ZMIN=SCALE*(Z(1)-SHIFT)
      DO 50 I=1,LZ
      Z(I)=SCALE*(Z(I)-SHIFT)
   50 IF(Z(I).LT.ZMIN) ZMIN=Z(I)
      WRITE(6,9)
    9 FORMAT(2X,'DO YOU WANT A LOG TRANSFORMATION?')
      READ(5,2) ANS
      FACTOR=0.
      IF(ANS.NE.Y) GO TO 55
      IF(ZMIN.GE.1. ) GO TO 31
      FACTOR=ZMIN-1.
   31 DO 35 I=1,LZ
   35 Z(I)=ALOG(Z(I)-FACTOR)
      ZMIN=ALOG(ZMIN-FACTOR)
      GO TO 150
   55 L=1
      WRITE(6,10)
   10 FORMAT(2X,'DO YOU WANT A POWER TRANSFORMATION, W=Z**P?')
      READ(5,2) ANS
      IF(ANS.NE.Y) GO TO 305
      WRITE(6,11)
   11 FORMAT(2X,'ENTER POWER P BETWEEN -10. AND 10. (P .NE. 0. OR 1.)')
  302 READ(5,4) P
      FRACT=P-AINT(P)
      IF(FRACT.NE.0.) GO TO 303
      IP=P
      DO 304 I=1,LZ
  304 Z(I)=Z(I)**IP
      GO TO 305
  303 IF(ZMIN.LE.0.) GO TO 306
      DO 307 I=1,LZ
  307 Z(I)=Z(I)**P
      GO TO 305
  306 WRITE(6,310) ZMIN
  310 FORMAT(2X,'A VALUE OF ',G12.6,'WAS SUBSTRACTED FROM EACH',
     *' OBSERVATION TO PREVENT ERRORS.')
      DO 309 I=1,LZ
      Z(I)=Z(I)-ZMIN
      FACTOR=ZMIN
      IF(Z(I).EQ.0.) GO TO 309
      Z(I)=Z(I)**P
  309 CONTINUE
  305 WRITE(6,100) SCALE,SHIFT,FACTOR,P
  100 FORMAT(2X,'TRANSFORMATION IS W(I)=(SCALE*(Z(I)-SHIFT)-C)**P WHERE'
     *':',//,3X,'SCALE=',G10.4,2X,'SHIFT=',G10.4,2X,'C=',G10.4,
     *2X,'P=',F8.4)
      GO TO 200
  150 WRITE(6,175) SCALE,SHIFT,FACTOR
```

```
175 FORMAT(2X,'TRANSFORMATION IS W(I)=LOG(SCALE*(Z(I)-SHIFT)',        TRA00710
   *'-FACTOR) WHERE:',//,3X,'SCALE=',G12.6,3X,'SHIFT=',G12.6,         TRA00720
   *3X,'FACTOR=',G12.6)                                               TRA00730
200 WRITE(3,400) LZ                                                   TRA00740
    WRITE(3,21) (Z(I),I=1,LZ)                                         TRA00750
    WRITE(7,217) L,SHIFT,SCALE,P,FACTOR                               TRA00760
217 FORMAT(I1,4E15.6)                                                 TRA00770
    STOP                                                              TRA00780
    END                                                               TRA00790
```

```
      DIMENSION X(999),IND(8),ARPS(10),PMAS(10),GR(40),ACV(25),PACV(25),
     *WKAREA(25),RANGE(4),T(25),AC(25)
      DATA ARPS,PMAS/20*0./,IND/4*0,100,3,0,3/
      EQUIVALENCE(A,B)
      REAL*8  A(999)
      REAL*4 B(1998)
      READ(2,200) IND(1)
  200 FORMAT(I3)
      L=IND(1)
      READ(2,201) (X(I),I=1,L)
  201 FORMAT(5E15.6)
      WRITE(6,600)
  600 FORMAT(2X,'ENTER NUMBER OF AR PARAMETERS (EXCLUDE DIFFERENCES).')
      READ(5,500) IND(2)
  500 FORMAT(I1)
      WRITE(6,601)
  601 FORMAT(2X,'ENTER NUMBER OF MA PARAMETERS.')
      READ(5,500) IND(3)
      CALL FTMAXL(X,IND,ARPS,PMAS,PMAC,WNV,GR,A,IER)
      WRITE(6,603) IND(1),IND(2),IND(3)
  603 FORMAT(2X,'LENGTH OF TIME SERIES =',I4/2X,I1,' AR PARAMETERS',4X,
     *I1,' MA PARAMETERS'/)
      WRITE(3,614) L
  614 FORMAT(I3)
      WRITE(3,613)  (B(I),I=1,L)
  613 FORMAT(5E15.6)
      WRITE(3,615)
  615 FORMAT(/,3X,'RESIDUAL VALUES.')
      N=IND(2)
      IF (N.EQ.0) GO TO 3002
      WRITE(6,605) (I,ARPS(I),I=1,N)
  605 FORMAT(2X,'AR PARAMETERS ARE:',/(2X,'PHI(',I1,')=',F9.4)/)
 3002 M=IND(3)
      IF(M.EQ.0) GO TO 3001
      WRITE(6,607) (I,PMAS(I),I=1,M)
  607 FORMAT(2X,'MA PARAMETERS ARE:'/(2X,'THETA(',I1,')=',F9.4)/)
 3001 WRITE(6,608) PMAC,WNV
  608 FORMAT(2X,'MA CONSTANT= ',E13.5,5X,'WHITE NOISE VARIANCE= ',
     *E15.6/)
      WRITE(4,200) N
      IF(N.LE.0) GO TO 72
      WRITE(4,201) (ARPS(I),I=1,N)
   72 WRITE(4,200) M
      IF(M.LE.0) GO TO 71
      WRITE(4,201) (PMAS(I),I=1,M)
   71 WRITE(4,201) PMAC
      IF(IER.EQ.0) GO TO 616
      WRITE(6,610) IER
  610 FORMAT(2X,'ERROR NUMBER=',I3)
  616 NDF = 25 - IND(2) - IND(3)
      CALL FTAUTO(B,L,25,25,7,AMEAN,VAR,ACV,AC,PACV,WKAREA)
      C=0.
      DO 4000 I=1,25
 4000 C=C+(AC(I))**2
      C=C*L
      CALL MDCHI(C,NDF,P,IER)
      SIGNIF=P
      WRITE(6,7) C,NDF,SIGNIF
    7 FORMAT(2X,'CHI SQUARE RESIDUAL LACK OF FIT VALUE =',F7.2,3X,
     *'DF =',I3,/,10X,'SIGNIFICANCE =',F7.4)
      STOP
      END
```

```
C
C        YESTSEAS CALCULATES INITIAL ESTIMATES OF ARIMA
C        PARAMETERS, BOTH SEASONAL AND NON-SEASONAL,
C        FOR INPUT INTO THE PROGRAM MARQRT.
C
      REAL*8 AVEC(1000),WA(50)
      REAL*4 B(2000),C(1000)
      EQUIVALENCE(AVEC,B)
      DIMENSION IND(8),ARPS(5),PMAS(5),GR(40)
      DIMENSION WVEC(1000),ANEW(1000),ACV(1000),AC(1000),PACV(25)
      DIMENSION WKAREA(200),SARPS(5),SPMAS(5)
C
C        INPUT PHASE
C
C
C        READ LSERIES AND TIME SERIES FROM FILE FT02F001
C
      READ(2,10)N
   10 FORMAT(I3)
      READ(2,11)(WVEC(I),I=1,N)
   11 FORMAT(5F15.6)
      WRITE(6,25)
   25 FORMAT(2X,'ENTER LENGTH OF SEASON VIA FORMAT I2.')
      READ(5,26)LSEAS
   26 FORMAT(I2)
      WRITE(6,65)
   65 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL DIFFERENCES.')
      READ(6,66)NDIFNS
   66 FORMAT(I1)
      WRITE(6,67)
   67 FORMAT(2X,'ENTER NUMBER OF SEASONAL DIFFERENCES.')
      READ(6,66)NDIFS
C
C        INPUT NUMBER OF PARAMETERS, BY TYPE.
C
      WRITE(6,60)
   60 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.')
      READ(5,61)IP
   61 FORMAT(I1)
      WRITE(6,62)
   62 FORMAT(2X,'ENTER NUMBER OF SEASONAL AR PARAMETERS.')
      READ(5,61)IPS
      WRITE(6,63)
   63 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.')
      READ(5,61)IQ
      WRITE(6,64)
   64 FORMAT(2X,'ENTER NUMBER OF SEASONAL MA PARAMETERS.')
      READ(5,61)IQS
C
C        DIFFERENCE WVEC USING NDIFNS AND NDIFS.
C
      IPFTR=1
      CALL FTRDIF(NDIFNS,NDIFS,IPFTR,LSEAS,N,WVEC,SHIFT,LW,IER)
C
C        NOW COMPUTE NON-SEASONAL PARAMETER ESTIMATES.
C
      IND(1)=LW
      IND(2)=IP
      IND(3)=IQ
      IND(4)=0
      IND(5)=100
      IND(6)=3
      IND(7)=0
      IND(8)=3
      CALL FTMAXL(WVEC,IND,ARPS,PMAS,PMAC,WNV,GR,AVEC,IER)
      WRITE(3,3)LW
    3 FORMAT(I3)
      WRITE(3,4)(B(I),I=1,LW)
    4 FORMAT(5E15.6)
      IF(IER.NE.0)WRITE(6,1000)IER
```

```
 1000 FORMAT(//,2X,'IER FROM FTMAXL=',I3)
      ISW=5
      L=0
      K=MINO(LW/4,LSEAS*10)
      CALL FTAUTO(B,LW,K,L,ISW,WBAR,VAR,ACV,AC,PACV,WKAREA)
      KK=K/LSEAS
      DO 900 I=1,KK
      ACV(I+1)=ACV(I*LSEAS)
  900 CONTINUE
      ACV(1)=VAR
      IF(IPS.EQ.0)GO TO 901
      CALL FTARPS(ACV,WBAR,IPS,ICS,SARPS,SPMAC,WA,IER)
      IF(IER.NE.0)WRITE(6,902)IER
  902 FORMAT(//,2X,'IER FROM FTARPS IS:',I3)
  901 IF(ICS.EQ.0)GO TO 903
      CALL FTMAPS(ACV,SARPS,IPS,ICS,SPMAS,WNV,WA,IER)
      IF(IER.NE.0)WRITE(6,904)IER
  904 FORMAT(//,2X,'IER FROM FTMAPS IS:',I3)
C
C        OUTPUT THE PARAMETER ESTIMATES.
C
  903 WRITE(6,20)
   20 FORMAT(//,2X,'INITIAL PARAMETER ESTIMATES FOR MARQRT :',//)
      IF(IP.EQ.0)GO TO 200
      DO 21 I=1,IP
      WRITE(6,22)I,ARPS(I)
   22 FORMAT(2X,'PHI(',I1,') =',F10.6)
   21 CONTINUE
  200 IF(IPS.EQ.0)GO TO 300
      DO 31 II=1,IPS
      WRITE(6,32)II,SARPS(II)
   32 FORMAT(2X,'PHIS(',I1,') =',F10.6)
   31 CONTINUE
  300 IF(IQ.EQ.0)GO TO 400
      DO 41 J=1,IQ
      WRITE(6,42)J,PMAS(J)
   42 FORMAT(2X,'THETA(',I1,') =',F10.6)
   41 CONTINUE
  400 IF(ICS.EQ.0)GO TO 500
      DO 51 JJ=1,ICS
      WRITE(6,52)JJ,SPMAS(JJ)
   52 FORMAT(2X,'THETAS(',I1,') =',F10.6)
   51 CONTINUE
  500 STOP
      END
```

```
C         INPUT PHASE
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION THETA(5),THETAS(5),PHI(5),PHIS(5),BETA(20),X(20,1000)
      DIMENSION BETAN(20),PHIN(5),PHISN(5),THETAN(5),THESN(5)
      DIMENSION  AVEC(1000),WVEC(1000),AMAT(20,20)
      DIMENSION STDERR(20),SEPI(5),SEPIS(5),SETH(5),SETHS(5)
      DIMENSION ACV(25),AC(25),PACV(25),WKAREA(40),WKAR1(30)
      DIMENSION AINV(20,20)
C
C         READ LSERIES AND TIME SERIES FROM FILE FT02F001
C
      READ(2,10)N
   10 FORMAT(I3)
      READ(2,11)(WVEC(I),I=1,N)
   11 FORMAT(5F15.6)
      WRITE(6,12)
   12 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL DIFFERENCES.')
      READ(5,13)NDIFNS
   13 FORMAT(I1)
      WRITE(6,14)
   14 FORMAT(2X,'ENTER NUMBER OF SEASONAL DIFFERENCES.')
      READ(5,13)NDIFS
C
C         INPUT NUMBER OF PARAMETERS, BY TYPE.
C
      WRITE(6,20)
   20 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.')
      READ(5,21)IP
   21 FORMAT(I1)
      WRITE(6,22)
   22 FORMAT(2X,'ENTER NUMBER OF SEASONAL AR PARAMETERS.')
      READ(5,21)IPS
      WRITE(6,23)
   23 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.')
      READ(5,21)IQ
      WRITE(6,24)
   24 FORMAT(2X,'ENTER NUMBER OF SEASONAL MA PARAMETERS.')
      READ(5,21)IQS
      LSEAS = 1
      IF((IPS.EQ.0).AND.(IQS.EQ.0))GO TO 5
      WRITE(6,25)
   25 FORMAT(2X,'ENTER LENGTH OF SEASON VIA FORMAT I2.')
      READ(5,26)LSEAS
26    FORMAT(I2)
C
C         INPUT YOUR INITIAL PARAMETER ESTIMATES
C
    5 WRITE(6,30)
   30 FORMAT(/,2X,'NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUES
     1TED.',/)
C         PERFORM DIFFERENCING
      ITRANS=1
      CALL FTRDIF(NDIFNS,NDIFS,ITRANS,LSEAS,N,WVEC,SHIFT,N,IER)
      IF(IP.EQ.0)GO TO 400
      DO 40 I=1,IP
      WRITE(6,41)I
   41 FORMAT(2X,'ENTER NON-SEASONAL AR PARAMETER PHI(',I1,').')
      READ(5,42)PHI(I)
   42 FORMAT(F15.6)
   40 CONTINUE
  400 IF(IPS.EQ.0)GO TO 500
      DO 50 J=1,IPS
      WRITE(6,51)J
   51 FORMAT(2X,'ENTER SEASONAL AR PARAMETER PHIS(',I1,').')
      READ(5,52)PHIS(J)
   52 FORMAT(F15.6)
   50 CONTINUE
  500 IF(IQ.EQ.0)GO TO 600
      DO 60 K=1,IQ
```

```
      WRITE(6,61)K
   61 FORMAT(2X,'ENTER NON-SEASONAL MA PARAMETER THETA(',I1,').')
      READ(5,62)THETA(K)
   62 FORMAT(F15.6)
   60 CONTINUE
  600 IF(IQS.EQ.0)GO TO 700
      DO 70 L=1,IQS
      WRITE(6,71)L
   71 FORMAT(2X,'ENTER SEASONAL MA PARAMETER THETAS(',I1,').')
      READ(5,72)THETAS(L)
   72 FORMAT(F15.6)
   70 CONTINUE
C
C        NOW CALL MARQRT TO CALCULATE THE LEAST SQUARES
C        ESTIMATES OF THE DESIRED MODEL PARAMETERS.
C
  700 CALL MARQRT(PHI,PHIS,THETA,THETAS,AVEC,X,WVEC,BETA,IP,IPS,IQ,IQS,N
     1,LSEAS,AMAT,SUMSQA)
      NPARAM=IP + IPS + IQ + IQS
C
C        CALCULATE THE STANDARD ERROR OF PARAMETER ESTIMATES
C
      SIG2AT = SUMSQA/DFLOAT(N-IP-IQ-IPS-IQS)
      IA = 20
      NORDER = NPARAM
      IDGT = 6
      CALL LINV1F(AMAT,NORDER,IA,AINV,IDGT,WKAREA,IER)
      DO 90 I=1,NPARAM
      STDERR(I) = (AINV(I,I)*SIG2AT)**.5
   90 CONTINUE
      CALL SWAPB(STDERR,IP,IPS,IQ,IQS,SEPI,SEPIS,SETH,SETHS)
C
C        WRITE OUT THE PARAMETERS AND THEIR STANDARD ERROR
C
      WRITE(6,91)
   91 FORMAT(//,12X,'PARAMETER ESTIMATE',13X,'STANDARD ERROR',//)
      IF(IP.EQ.0)GO TO 92
      DO 101 I=1,IP
      WRITE(6,102)I,PHI(I),SEPI(I)
  102 FORMAT(12X,'PHI(',I1,') =',F10.6,12X,E13.6)
  101 CONTINUE
   92 IF(IPS.EQ.0)GO TO 93
      DO 103 J=1,IPS
      WRITE(6,104)J,PHIS(J),SEPIS(J)
  104 FORMAT(12X,'PHIS(',I1,') =',F10.6,11X,E13.6)
  103 CONTINUE
   93 IF(IQ.EQ.0)GO TO 94
      DO 105 K=1,IQ
      WRITE(6,106)K,THETA(K),SETH(K)
  106 FORMAT(12X,'THETA(',I1,') =',F10.6,10X,E13.6)
  105 CONTINUE
   94 IF(IQS.EQ.0)GO TO 95
      DO 107 L=1,IQS
      WRITE(6,108)L,THETAS(L),SETHS(L)
  108 FORMAT(12X,'THETAS(',I1,') =',F10.6,9X,E13.6)
  107 CONTINUE
C
C        CALCULATE THE MOVING AVERAGE CONSTANT, THETA0
C
   95 SUM=0.0D0
      DO 96 J=1,N
      SUM = SUM + WVEC(J)
   96 CONTINUE
      WMEAN = SUM/DFLOAT(N)
      SUM1 = 0.0D0
      IF(IP.EQ.0)GO TO 971
      DO 972 II=1,IP
      SUM1 = SUM1 + PHI(II)
  972 CONTINUE
  971 SUM2 = 0.0D0
```

```
      IF(IPS.EQ.0)GO TO 973
      DO 974 LL=1,IPS
      SUM2 = SUM2 + PHIS(LL)
  974 CONTINUE
  973 THETAO = (1.0D0-SUM1)*(1.0D0-SUM2)*WMEAN
      WRITE(6,975)THETAO
  975 FORMAT(//,12X,'MOVING AVERAGE CONSTANT: THETAO = ',F10.6,//)
C
C        CALCULATE THE AUTOS AND PAUTOS OF RESIDUALS
C
      LW = N - NDIFNS - NDIFS
      K = 40
      L = 40
      ISW = 7
      WRITE(3,10)LW
      WRITE(3,11)(AVEC(I),I=1,LW)
      CALL FTAUTO(AVEC,LW,K,L,ISW,AMEAN,VAR,ACV,AC,PACV,WKAR1)
C
C
C        CALL MDCDFI TO GET CHI-SQUARE GOODNESS OF FIT INFO
C
      SUM3 = 0.0D0
      DO 669 I=1,K
      SUM3 = SUM3 + AC(I)**2
  669 CONTINUE
      CHISQR = DFLOAT(N)*SUM3
      NDF = K - (IP+IPS + IQ + IQS)
      CALL MDCDFI(CHISQR,NDF,Q,IER)
      WRITE(6,670)CHISQR,NDF,Q
  670 FORMAT(//,12X,'CHI-SQUARE STATISTIC FOR RESIDUAL LACK OF FIT =',F1
     10.6,//,12X,'DEGREES OF FREEDOM =',I3,//,12X,'PROBABILITY OF EXCEED
     2ING STATISTIC =',F10.6,//)
C
      WRITE(3,790)N
  790 FORMAT(I3)
      WRITE(3,791)(AVEC(I),I=1,N)
  791 FORMAT(5F15.6)
      STOP
      END
```

```
      SUBROUTINE MARCRT(PHI,PHIS,THETA,THETAS,AVEC,X,WVEC,BETA,IP,IPS,IQ
     1,IQS,N,LSEAS,AMAT,SUMSCA)
C
C        MARQUART IS A NON-LINEAR LEAST-SQUARES OPTIMIZING
C        ROUTINE FOR THE ESTIMATION OF PARAMETERS FOR
C        A GENERALIZED SEASONAL ARIMA TIME SERIES MODEL.
C
      DOUBLE PRECISION X,AMAT,ASTARM
      DOUBLE PRECISION PHI,PHIS,THETA,THETAS,PHIN,PHISN,THETAN,THESN
      DOUBLE PRECISION AVEC,DVEC,WVEC,GVEC,GSTARV,HVEC,HSTARV
      DOUBLE PRECISION WKAREA
      DOUBLE PRECISION BETA,BETAN,CONSPI,F2,EPS,SUM,SUMG
      DOUBLE PRECISION SUMSCA,SUMSCN
      DIMENSION X(20,1000),AVEC(1000),AMAT(20,20),DVEC(20)
      DIMENSION GVEC(20),ASTARM(20,20),GSTARV(20),HVEC(20)
      DIMENSION BETA(20),HSTARV(20),BETAN(20),PHI(5),PHIN(5),PHIS(5)
      DIMENSION PHISN(5),THETA(5),THETAN(5),THETAS(5)
      DIMENSION THESN(5),WVEC(1000)
      DIMENSION WKAREA(1000)
      DATA IA/20/,M/1/
C
      CONSPI = .01D0
      F2 = C.C1D0
      EPS=C.00001D0
      KCUNT=0
      KCUNT1 = 0
C
C        CALL PARSH TO GET REQUIRED DERIVATIVES
C
C
C        STAGE 1
C
   30 KCUNT=KCUNT+1
      IF(KCUNT.EQ.50)GO TO 999
      CALL PARSH(IP,IPS,IQ,IQS,PHI,PHIS,THETA,THETAS,AVEC,X,N,WVEC,LSEAS
     1)
C
C        CALL SUMSQ TO GET ACTUAL AVEC AND SUMSQ.
C
      CALL SUMSQ(PHI,PHIS,THETA,THETAS,N,WVEC,IP,IPS,IQ,IQS,LSEAS,
     1SUMSCA,AVEC)
C
C     FORM THE A MATRIX
C
      NPARAM=IP + IPS + IQ + IQS
      DO 1 I=1,NPARAM
      DO 2 J=1,NPARAM
      SUM = 0.0D0
         DO 3 IJ=1,N
         SUM=SUM + X(I,IJ)*X(J,IJ)
    3    CONTINUE
      AMAT(I,J)=SUM
    2 CONTINUE
    1 CONTINUE
C
C        FORM THE G VECTOR.
C
      DO 4 II=1,NPARAM
      SUMG = C.0D0
      DO 5 JJ=1,N
      SUMG=SUMG + X(II,JJ)*AVEC(JJ)
    5 CONTINUE
      GVEC(II)=SUMG
    4 CONTINUE
C
C        FORM THE SCALING VECTOR, CALLED DVEC.
C
      DO 6 JJJ=1,NPARAM
      DVEC(JJJ)=AMAT(JJJ,JJJ)**.5
    6 CONTINUE
```

```
C
C         FORM THE "STARREC" ARRAYS, BY RESCALING USING
C         THE DVEC. SEE BOX & JENKINS, PAGE 504 AND 505.
C
C
C         STAGE 2
C
   50 KOUNT1 = KOUNT1 + 1
      IF(KOUNT1.EQ.50)GO TO 999
      DO 7 K=1,NPARAM
      DO 8 KK=1,NPARAM
      ASTARM(K,KK) = (AMAT(K,KK)/DVEC(K))/DVEC(KK)
      IF(K.EQ.KK)ASTARM(K,KK)=1.0D0 + CONSPI
    8 CONTINUE
    7 CONTINUE
C
      DO 9 KKK=1,NPARAM
      GSTARV(KKK)=GVEC(KKK)/DVEC(KKK)
    9 CONTINUE
C
C         NOW SOLVE THE LINEAR SYSTEM ASTARM * HVEC = GSTARV.
C
      IDGT=6
C
      CALL LEQT2F(ASTARM,M,NPARAM,IA,GSTARV,IDGT,WKAREA,IER)
C
C         ASSIGN OUTPUT (SOLUTION) TO HVEC.
C
      DO 10 L=1,NPARAM
      HSTARV(L)=GSTARV(L)
      HVEC(L)=HSTARV(L)/DVEC(L)
   10 CONTINUE
C
C         CALCULATE THE NEW BETA VECTOR OF PARAMETERS;
C         FIRST,PUT THE NEW PARAMETERS IN BETA VECTOR FORM.
C
      CALL FORMB(PHI,PHIS,THETA,THETAS,IP,IPS,IQ,IQS,BETA)
C
C         NOW, FORM THE NEW BETA VECTOR, USING THE H VECTOR.
C
      DO 11 MM=1,NPARAM
      BETAN(MM) = BETA(MM) + HVEC(MM)
   11 CONTINUE
C
C         STAGE 3
C
C         NOW, EVALUATE THE SUM OF SQUARES OF THE RESIDUALS
C         USING THESE NEW PARAMETERS, AND COMPARE TO THE OLD
C         VALUES.
C
      CALL SWAPB(BETAN,IP,IPS,IQ,IQS,PHIN,PHISN,THETAN,THESN)
      CALL SUMSQ(PHIN,PHISN,THETAN,THESN,N,WVEC,IP,IPS,IQ,IQS,LS
     1EAS,SUMSQN,AVEC)
C
C         TEST THE RESULTS; REFER TO BOX & JENKINS PAGE 506.
C
      IF(SUMSQN.LE.SUMSQA)GO TO 20
      CONSPI=CONSPI/F2
      IF(CONSPI.GT.1.0E+58)GO TO 995
C
C         RETURN TO STAGE (2).
C
      GO TO 50
C
   20 DO 35 LL=1,NPARAM
      IF(DABS(HVEC(LL)).LT.EPS)GO TO 35
      GO TO 40
   35 CONTINUE
      GO TO 60
C
```

```
C                                                                       MAR01400
   40 DO 45 LLL=1,NPARAM                                                MAR01410
      BETA(LLL) = BETAN(LLL)                                            MAR01420
   45 CONTINUE                                                          MAR01430
      CALL SWAPB(BETA,IP,IPS,IQ,IQS,PHI,PHIS,THETA,THETAS)              MAR01440
      CONSPI=CONSPI*F2                                                  MAR01450
      IF(CONSPI.LT.1.0E-60)GO TO 995
C                                                                       MAR01460
C        GO TO STAGE (1).                                               MAR01470
C                                                                       MAR01480
      GO TO 30                                                          MAR01490
C                                                                       MAR01500
C                                                                       MAR01510
   60 WRITE(6,61)KOUNT,KOUNT1                                           MAR01520
   61 FORMAT(//,2X,'CONVERGENCE HAS BEEN REACHED IN MAX(',I2,',',I2,')
     1ITERATIONS.',//)                                                  MAR01540
      WRITE(6,62)                                                       MAR01550
   62 FORMAT(/,2X,'SELECTED OUTPUT FOLLOWS:')                           MAR01560
C                                                                       MAR01570
C        ASSIGN FINAL BETA VALUES TO THE BETA VECTOR.                   MAR01580
C                                                                       MAR01590
      DO 63 I1=1,NPARAM                                                 MAR01600
      BETA(I1)=BETAN(I1)                                                MAR01610
   63 CONTINUE                                                          MAR01620
C                                                                       MAR01630
C        NOW, PUT IN THE PROPER FORM FOR OUTPUT.                        MAR01640
C                                                                       MAR01650
      CALL SWAPB(BETAN,IP,IPS,IQ,IQS,PHI,PHIS,THETA,THETAS)             MAR01660
      GO TO 1000                                                        MAR01670
C                                                                       MAR01680
  995 WRITE(6,996)
  996 FORMAT(//,2X,'COMPUTATIONS TERMINATED; CONSPI PARAMETER EXCEEDED B
     1OUNDS;',//,2X,'CHECK YOUR INITIAL ESTIMATES OF PARAMETERS AND OTHE
     2R INPUT DATA.')
      GO TO 1000
C                                                                       MAR01690
  999 WRITE(6,998)                                                      MAR01700
  998 FORMAT(2X,'KOUNT, ITERATION MAX KOUNT, HAS BEEN EXCEEDED;',/,2    MAR01710
     1X,'THIS RUN HAS BEEN TERMINATED.')                                MAR01720
 1000 RETURN                                                            MAR01730
      END                                                               MAR01740
```

```
      SUBROUTINE SUMSQ(PHI,PHIS,THETA,THETAS,N,WVEC,IP,IPS,IQ,IQS,
     1LSEAS,SUMSQA,AVEC)
      DOUBLE PRECISION AVEC,TAVEC,PI,GAMMA
      DOUBLE PRECISION EVEC,WVEC,TVEC,SUMPI,SUMTHE,SUMSQA
      DOUBLE PRECISION PHI,PHIS,THETA,THETAS,PHIT,PHIST,THETAT,THEST
      DIMENSION WVEC(1000),EVEC(1000),AVEC(1000),INDAR(100)
      DIMENSION INDMA(100),PI(100),GAMMA(100),PHI(5),PHIS(5)
      DIMENSION THETA(5),THETAS(5), PHIT(5),PHIST(5),THETAT(5)
      DIMENSION THEST(5),TVEC(1000),TAVEC(1000)
C
C        THIS SUBROUTINE CALCULATES THE VALUE OF THE SUM OF
C        SQUARED RESIDUALS AND ALSO PRODUCES THE VECTOR OF
C        RESIDUAL TERMS, THE AVEC.
C
C        HERE, 1 IS ADDED TO THE NUMBER OF PARAMETERS SO THAT
C        THE "1" TERMS IN THE POLYNOMIALS OF BACKWARD DIFFERENCE
C        OPERATORS CAN BE ACCOUNTED FOR IN THE EXPANSION.
C
      IPT=IP+1
      IPST=IPS+1
      IQT=IQ+1
      IQST=IQS+1
      IADDIT = IPT + (IPST*LSEAS) + IQT + (IQST*LSEAS) + 2
C
C        MOVE THE ORIGIN BY IADDIT ON THE WVEC.
C        THIS TAKES CARE OF THE NEGATIVE SUBSCRIPT PROBLEM
C        ENCOUNTERED IN BACKCASTING.
C
C        TVEC IS THE TEMPORARY WVEC FOR CALCULATIONS;
C        TAVEC IS THE TEMPORARY AVEC.
C
      DO 50 I=1,N
      K=I+IADDIT
      TVEC(K)=WVEC(I)
   50 CONTINUE
C
      DO 51 II=1,IADDIT
      TVEC(II) = 0.0D0
   51 CONTINUE
C
C        ZERO OUT THE TAVEC AND THE EVEC.
C
      K=N+IADDIT
      DO 55 I=1,K
      EVEC(I) = 0.0D0
      TAVEC(I) = 0.0D0
   55 CONTINUE
C
C        SHIFT THE ORIGIN ON THE PARAMETER VECTORS, AND
C        ASSIGN THEM TO TEMPORARY VECTORS.
C
      IF(IP.EQ.0)GO TO 111
      DO 11 MM=1,IP
      MM1=MM+1
      PHIT(MM1)=PHI(MM)
   11 CONTINUE
  111 IF(IPS.EQ.0)GO TO 112
      DO 12 MMM=1,IPS
      MMM1=MMM+1
      PHIST(MMM1)=PHIS(MMM)
   12 CONTINUE
  112 IF(IQ.EQ.0)GO TO 113
      DO 13 LL=1,IQ
      LL1=LL+1
      THETAT(LL1)=THETA(LL)
   13 CONTINUE
  113 IF(IQS.EQ.0)GO TO 114
      DO 14 LLL=1,IQS
      LLL1=LLL+1
      THEST(LLL1)=THETAS(LLL)
```

```
   14 CONTINUE
  114 PHIT(1) = 1.0D0
      PHIST(1) = 1.0D0
      THETAT(1) = 1.0D0
      THEST(1) = 1.0D0
C
C        UNRAVEL THE AR SIDE OF THE GENERAL MODEL;
C        KAR WILL KEEP TRACK OF THE NUMBER OF NON-ZERO
C        ELEMENTS OF THE PI VECTOR OF PARAMETERS.
C
      KAR=0
      DO 200 J=1,IPST
      DO 100 I=1,IPT
      KAR=KAR+1
      K=(I-1) + (J-1)*LSEAS
      INDAR(KAR)=K + IADDIT
      PI(KAR) = PHIT(I)*PHIST(J)
      IF(((J.EQ.1).AND.(I.EQ.1)).OR.((J.GT.1).AND.(I.GT.1)))PI(KAR)=
     1-PI(KAR)
  100 CONTINUE
  200 CONTINUE
C
C        NOW UNRAVEL THE MA SIDE OF THE MODEL, FORMING THE
C        NON-ZERO ELEMENTS OF THE GAMMA VECTOR.
C
      KMA=0
      DO 300 JJ=1,IQST
      DO 400 II=1,IQT
      KMA=KMA+1
      KK=(II-1) + (JJ-1)*LSEAS
      INDMA(KMA)=KK + IADDIT
      GAMMA(KMA) = THETAT(II)*THEST(JJ)
      IF(((JJ.EQ.1).AND.(II.EQ.1)).OR.((JJ.GT.1).AND.(II.GT.1)))GAMMA(KM
     1A)=-GAMMA(KMA)
  400 CONTINUE
  300 CONTINUE
C
C        NOW, SOLVE FOR THE NON-ZERO ELEMENTS OF THE EVEC.
C
      DO 210 I=1,10
      I1 = 11 - I
      SUMPI = 0.0D0
      IF((IP.EQ.0).AND.(IPS.EQ.0))GO TO 215
      DO 220 J=2,KAR
      KKK=INDAR(J)
      I11=I1+KKK
      SUMPI = SUMPI + PI(J)*TVEC(I11)
  220 CONTINUE
  215 SUMTHE = 0.0D0
      IF((IQ.EQ.0).AND.(IQS.EQ.0))GO TO 225
      DO 230 K=2,KMA
      JJJ=INDMA(K)
      I12=I1 + JJJ
      SUMTHE=SUMTHE + GAMMA(K)*EVEC(I12)
  230 CONTINUE
  225 EVEC(I1) = TVEC(I1) + SUMPI - SUMTHE
  210 CONTINUE
C
C        NOW, BACKCAST THE REQUIRED WVEC VALUES.
C
      DO 310 I=1,IADDIT
      I2 = 1 - I
      SUMPI = 0.0D0
      IF((IP.EQ.0).AND.(IPS.EQ.0))GO TO 315
      DO 320 J=2,KAR
      KKK=INDAR(J)
      I21=I2 + KKK
      SUMPI = SUMPI + PI(J)*TVEC(I21)
  320 CONTINUE
  315 SUMTHE = 0.0D0
```

```
      IF((IC.EQ.0).AND.(ICS.EQ.0))GO TO 325
      DO 330 K=2,KMA
      JJJ=INDMA(K)                                                      NLEC3470
      I22=I2 + JJJ
      SUMTHE=SUMTHE + GAMMA(K)*EVEC(I22)
  330 CONTINUE                                                          NLE03490
  325 I23 = 1 - I + IADDIT
      TVEC(I23) = EVEC(I23) + SUMPI - SUMTHE
  310 CONTINUE                                                          NLEC3510
C                                                                       NLEC3520
C        NOW, CALCULATE THE AVEC VALUES.                                NLEC3530
C                                                                       NLE03540
      DO 410 I=1,N                                                      NLE03550
      I3 = IADDIT + I
      SUMPI = 0.0D0
      IF((IP.EQ.0).AND.(IPS.EQ.0))GO TO 415
      DO 420 J=2,KAR
      KKK = INDAR(J) - IADDIT
      I31 = I - KKK + IADDIT
      SUMPI = SUMPI + FI(J)*TVEC(I31)
  420 CONTINUE                                                          NLE03610
  415 SUMTHE = 0.0D0
      IF((IQ.EQ.0).AND.(IQS.EQ.0))GO TO 425
      DO 430 K=2,KMA
      JJJ = INDMA(K) - IADDIT
      I32 = I - JJJ + IADDIT
      SUMTHE=SUMTHE + GAMMA(K)*TAVEC(I32)
  430 CONTINUE                                                          NLE03660
  425 TAVEC(I3) = TVEC(I3) - SUMPI + SUMTHE
  410 CONTINUE                                                          NLE03680
C                                                                       NLEC3690
C        CALCULATE THE SUM OF SQUARES, THE AVEC(I)'S SQUARED            NLE03700
C        AND SUMMED, OVER ALL VALUES OF THE TIME SERIES.                NLE03710
C                                                                       NLE03720
      SUMSQA = 0.0D0
      DO 440 I=1,N                                                      NLE03740
      I4 = IADDIT + I
      SUMSQA = SUMSQA + TAVEC(I4)**2
  440 CONTINUE                                                          NLEC3770
C                                                                       NLE03780
C        FOR OUTPUT PURPOSES, CORRECT THE ORIGIN FOR THE AVEC           NLEC3790
C        INDICES, SO THAT THEY WILL RUN FROM 1 TO N.                    NLE03800
C                                                                       NLEC3810
      DO 1 I=1,N                                                        NLEC3820
      I44=IADDIT + I
      AVEC(I) = TAVEC(I44)
    1 CONTINUE                                                          NLE03840
      RETURN                                                            NLEC3850
      END                                                               NLEC3860
```

```
      SUBROUTINE PARSH(IP,IPS,IQ,IQS,PHI,PHIS,THETA,THETAS,AVEC,X,N,WVEC
     1,LSEAS)
      DOUBLE PRECISION X,AVEC,TOP1,TOP2,WVEC,DELTA,SUMSQA
      DOUBLE PRECISION PHI,PHIS,THETA,THETAS,PHIT,PHIST,THETAT,THEST
      DIMENSION AVEC(1000),X(20,1000),PHI(5),PHIS(5),THETA(5)
      DIMENSION THETAS(5),PHIT(5),PHIST(5),THETAT(5),THEST(5)
      DIMENSION TOP1(1000),TOP2(1000)
      DIMENSION WVEC(1000)
      DELTA = 0.0000000001D0
C
C        THIS SUBROUTINE CALCULATES THE DERIVATIVES USED
C        IN THE NON-LINEAR LEAST SQUARES ROUTINE.
C
      CALL SUMSQ(PHI,PHIS,THETA,THETAS,N,WVEC,IP,IPS,IQ,IQS,LSEAS,
     1SUMSQA,AVEC)
      DO 1 K=1,N
      TOP1(K)=AVEC(K)
    1 CONTINUE
C
C        ASSIGN ALL PARAMETER VALUES TO TEMPORARY VARIABLES.
C
      IF(IP.EQ.0)GO TO 991
      DO 91 I1=1,IP
      PHIT(I1)=PHI(I1)
   91 CONTINUE
  991 IF(IPS.EQ.0)GO TO 992
      DO 92 J1=1,IPS
      PHIST(J1)=PHIS(J1)
   92 CONTINUE
  992 IF(IQ.EQ.0)GO TO 993
      DO 93 K1=1,IQ
      THETAT(K1)=THETA(K1)
   93 CONTINUE
  993 IF(IQS.EQ.0)GO TO 994
      DO 94 L1=1,IQS
      THEST(L1)=THETAS(L1)
   94 CONTINUE
C
C        NOW, THE ROUTINE DOES PERTURBATIONS OF DELTA ON
C        EACH PARAMETER, TO OBTAIN INFORMATION ON THE
C        CONSEQUENT CHANGES TO THE RESIDUALS, IN ORDER
C        TO CALCULATE THE REQUIRED PARTIAL DERIVATIVES.
C
C        THE X(I,J)'S ARE THE DERIVATIVES.
C
  994 IF(IP.EQ.0)GO TO 200
      DO 2 J=1,IP
      PHIT(J)=PHIT(J) + DELTA
      CALL SUMSQ(PHIT,PHIS,THETA,THETAS,N,WVEC,IP,IPS,IQ,IQS,LSEAS
     1,SUMSQA,AVEC)
      DO 22 JJ=1,N
      TOP2(JJ)=AVEC(JJ)
      X(J,JJ) = (TOP1(JJ) - TOP2(JJ))/DELTA
   22 CONTINUE
      PHIT(J)=PHIT(J) - DELTA
    2 CONTINUE
  200 IF(IPS.EQ.0)GO TO 300
      DO 3 L=1,IPS
      PHIST(L)=PHIST(L) + DELTA
      CALL SUMSQ(PHI,PHIST,THETA,THETAS,N,WVEC,IP,IPS,IQ,IQS,LSEAS
     1,SUMSQA,AVEC)
      DO 33 LL=1,N
      TOP2(LL)=AVEC(LL)
      K3=L + IP
      X(K3,LL) = (TOP1(LL) - TOP2(LL))/DELTA
   33 CONTINUE
      PHIST(L)=PHIST(L) - DELTA
    3 CONTINUE
  300 IF(IQ.EQ.0)GO TO 400
      DO 4 M=1,IQ
```

```
      THETAT(M)=THETAT(M) + DELTA                                       NLE04450
      CALL SUMSQ(PHI,PHIS,THETAT,THETAS,N,WVEC,IP,IPS,IQ,IQS,LSEAS      NLE04460
     1,SUMSQA,AVEC)                                                     NLE04470
      DO 44 MM=1,N                                                      NLE04480
      TOP2(MM) = AVEC(MM)                                               NLE04490
      K4=M + IP + IPS                                                   NLE04500
      X(K4,MM) = (TOP1(MM) - TOP2(MM))/DELTA
   44 CONTINUE                                                          NLE04520
      THETAT(M) = THETAT(M) - DELTA                                     NLE04530
    4 CONTINUE                                                          NLE04540
  400 IF(IQS.EQ.0)GO TO 500                                             NLE04550
      DO 5 M1=1,IQS                                                     NLE04560
      THEST(M1) = THEST(M1) + DELTA                                     NLE04570
      CALL SUMSQ(PHI,PHIS,THETA,THEST,N,WVEC,IP,IPS,IQ,IQS,LSEAS        NLE04580
     1,SUMSQA,AVEC)                                                     NLE04590
      DO 55 MM1=1,N                                                     NLE04600
      TOP2(MM1)=AVEC(MM1)                                               NLE04610
      K5 = M1 + IP + IPS + IQ                                           NLE04620
      X(K5,MM1) = (TOP1(MM1) - TOP2(MM1))/DELTA                         NLE04630
   55 CONTINUE                                                          NLE04640
      THEST(M1) = THEST(M1) - DELTA                                     NLE04650
    5 CONTINUE                                                          NLE04660
  500 RETURN                                                            NLE04670
      END                                                               NLE04680
```

```
05/16/78  13.22.13

FILE: FORMB     FORTRAN  P1                NAVAL POSTGRADUATE SCHOOL                          PAGE 001

      SUBROUTINE FORMB(PHI,PHIS,THETA,THETAS,IP,IPS,IQ,IQS,BETA)          NLE04690
      DOUBLE PRECISION PHI,PHIS,THETA,THETAS,BETA
      DIMENSION BETA(20),PHI(5),PHIS(5),THETA(5),THETAS(5)                NLE04700
C                                                                         NLE04710
C         THIS SUBROUTINE TAKES SEPARATE PARAMETER VECTORS                NLE04720
C         AND PUTS THEM INTO COMBINED BETA VECTOR FORM.                   NLE04730
C                                                                         NLE04740
      IF(IP.EQ.0)GO TO 10                                                 NLE04750
      DO 1 I=1,IP                                                         NLE04760
      BETA(I)=PHI(I)                                                      NLE04770
    1 CONTINUE                                                            NLE04780
   10 IF(IPS.EQ.0)GO TO 20                                                NLE04790
      DO 2 J=1,IPS                                                        NLE04800
      KK=J+IP                                                             NLE04810
      BETA(KK)=PHIS(J)                                                    NLE04820
    2 CONTINUE                                                            NLE04830
   20 IF(IQ.EQ.0)GO TO 30                                                 NLE04840
      DO 3 K=1,IQ                                                         NLE04850
      KKK=K+IP+IPS                                                        NLE04860
      BETA(KKK)=THETA(K)                                                  NLE04870
    3 CONTINUE                                                            NLE04880
   30 IF(IQS.EQ.0)GO TO 40                                                NLE04890
      DO 4 L=1,IQS                                                        NLE04900
      KKKK=L+IP+IPS+IQ                                                    NLE04910
      BETA(KKKK)=THETAS(L)                                                NLE04920
    4 CONTINUE                                                            NLE04930
   40 RETURN                                                              NLE04940
      END                                                                 NLE04950
```

```
      SUBROUTINE SWAPE(BETAN,IP,IPS,IQ,IQS,PHIN,PHISN,THETAN,THESN)
      DOUBLE PRECISION PHIN,PHISN,THETAN,THESN,BETAN
      DIMENSION BETAN(20),PHIN(5),PHISN(5),THETAN(5),THESN(5)
C
C         THIS SUBROUTINE TAKES A BETAVEC AND PUTS IT
C         INTO SEPARATE PARAMETER VECTOR FORM.
C
      IF(IP.EQ.0)GO TO 10
      DO 1 I=1,IP
      PHIN(I)=BETAN(I)
    1 CONTINUE
   10 IF(IPS.EQ.0)GO TO 20
      DO 2 J=1,IPS
      JJ=J+IP
      PHISN(J)=BETAN(JJ)
    2 CONTINUE
   20 IF(IQ.EQ.0)GO TO 30
      DO 3 K=1,IQ
      KK=K+IP+IPS
      THETAN(K)=BETAN(KK)
    3 CONTINUE
   30 IF(IQS.EQ.0)GO TO 40
      DO 4 L=1,IQS
      LL=L+IP+IPS+IQ
      THESN(L)=BETAN(LL)
    4 CONTINUE
   40 RETURN
      END
```

```
09/16/78  13.22.37
FILE: XSUMSQ    FORTRAN  P1                NAVAL POSTGRADUATE SCHOOL                PAGE 001
C
C
C         THIS ROUTINE, XSUMSQ, CALCULATES THE SUM OF
C         SQUARED RESIDUALS FOR ANY ARIMA MODEL, GIVEN
C         A TIME SERIES AND INITIAL PARAMETER ESTIMATES.
C
C         INPUT PHASE
C
      REAL*8 WVEC(1000),AVEC(1000),PHI(5),PHIS(5),THETA(5),THETAS(5),
     *SUMSQA
      DATA Y/'Y'/
C
C         READ ASERIES AND TIME SERIES FROM FILE FT02F001
C
      READ(2,10)NS
   10 FORMAT(I3)
      READ(2,11)(WVEC(I),I=1,NS)
   11 FORMAT(5F15.6)
C
C         INPUT NUMBER OF PARAMETERS, BY TYPE.
C
      IPS=0
      IQS=0
  704 LSEAS=1
      WRITE(6,705)
  705 FORMAT(//,2X,'IS YOUR SERIES SEASONAL?')
      READ(5,708)ANS
  708 FORMAT(A1)
      IF(ANS.NE.Y)GO TO 706
      WRITE(6,25)
   25 FORMAT(2X,'ENTER LENGTH OF SEASON VIA FORMAT I2.')
      READ(5,26)LSEAS
26    FORMAT(I2)
      WRITE(6,22)
   22 FORMAT(2X,'ENTER NUMBER OF SEASONAL AR PARAMETERS.')
      READ(5,21)IPS
      WRITE(6,24)
   24 FORMAT(2X,'ENTER NUMBER OF SEASONAL MA PARAMETERS.')
      READ(5,21)IQS
  706 WRITE(6,20)
   20 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.')
      READ(5,21)IP
   21 FORMAT(I1)
      WRITE(6,23)
   23 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.')
      READ(5,21)IQ
C
C         INPUT YOUR INITIAL PARAMETER ESTIMATES
C
  702 WRITE(6,30)
   30 FORMAT(/,2X,'NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUES
     1TED.',/)
      IF(IP.EQ.0)GO TO 400
      DO 40 I=1,IP
      WRITE(6,41)I
   41 FORMAT(2X,'ENTER NON-SEASONAL AR PARAMETER PHI(',I1,').')
      READ(5,42)PHI(I)
   42 FORMAT(F15.6)
   40 CONTINUE
  400 IF(IPS.EQ.0)GO TO 500
      DO 50 J=1,IPS
      WRITE(6,51)J
   51 FORMAT(2X,'ENTER SEASONAL AR PARAMETER PHIS(',I1,').')
      READ(5,52)PHIS(J)
   52 FORMAT(F15.6)
   50 CONTINUE
  500 IF(IQ.EQ.0)GO TO 600
      DO 60 K=1,IQ
      WRITE(6,61)K
   61 FORMAT(2X,'ENTER NON-SEASONAL MA PARAMETER THETA(',I1,').')
      READ(5,62)THETA(K)
```

```
   62 FORMAT(F15.6)
   60 CONTINUE
  600 IF(IQS.EQ.0)GO TO 700
      DO 70 L=1,IQS
      WRITE(6,71)L
   71 FORMAT(2X,'ENTER SEASONAL MA PARAMETER THETAS(',I1,').')
      READ(5,72)THETAS(L)
   72 FORMAT(F15.6)
   70 CONTINUE
C
C        NOW CALL SUMSQ TO CALCULATE SUM OF SQUARED RESIDUALS.
C
  700 CALL SUMSQ(PHI,PHIS,THETA,THETAS,NS,WVEC,IP,IPS,IQ,IQS,LSEAS,SUMSQ
     1A,AVEC)
C
C        OUTPUT SUM OF SQUARES
C
      WRITE(6,99)SUMSQA
   99 FORMAT(//,10X,'FOR THE GIVEN INPUT PARAMETERS AND MODEL',//,10X,'T
     1HE RESIDUAL SUM OF SQUARES IS: ',E20.8,//)
      WRITE(6,13)
   13 FORMAT(//,2X,'DO YOU WANT TO TEST DIFFERENT PARAMETER VALUES?')
      READ(5,701)ANS
  701 FORMAT(A1)
      IF(ANS.EQ.Y)GO TO 702
      WRITE(6,703)
  703 FORMAT(//,2X,'DO YOU WANT TO TEST A DIFFERENT MODEL?')
      READ(5,701)ANS
      IF(ANS.EQ.Y)GO TO 704
      STOP
      END
```

```
      DIMENSION FCST(3,100),LV(5)
      DIMENSION WVEC(1000),PHI(5),PHIS(5),THETA(5),THETAS(5)
      DIMENSION PHIT(5),PHIST(5),THETAT(5),THEST(5)
      DIMENSION INDAR(100),INDMA(100),PI(100),GAMMA(100)
      DIMENSION GAMNEW(100),PINEW(100),PMAS(100),ARPS(100),DARPS(200)
      DIMENSION X(400),T(400),W(400),G(400),V(400),FL(200),FU(200)
      DIMENSION RANGE(4)
      DATA Y/'Y'/
C
C        INPUT PHASE
C
C        READ LSERIES AND TIME SERIES FROM FILE FT02F001
C
      READ(2,10)N
   10 FORMAT(I3)
      READ(2,11)(WVEC(I),I=1,N)
   11 FORMAT(5F15.6)
C
C        INPUT NUMBER OF PARAMETERS, BY TYPE.
C
      WRITE(6,1)
    1 FORMAT(/,2X,'IS YOUR SERIES SEASONAL?')
      READ(5,2)ANS
    2 FORMAT(A1)
      IF(ANS.NE.Y)GO TO 202
      WRITE(6,141)
  141 FORMAT(/,2X,'ENTER SEASONAL DATA AS REQUESTED:',/)
      WRITE(6,14)
   14 FORMAT(2X,'ENTER NUMBER OF SEASONAL DIFFERENCES.')
      READ(5,13)NDIFS
      WRITE(6,22)
   22 FORMAT(2X,'ENTER NUMBER OF SEASONAL AR PARAMETERS.')
      READ(5,21)IPS
      WRITE(6,24)
   24 FORMAT(2X,'ENTER NUMBER OF SEASONAL MA PARAMETERS.')
      READ(5,21)IQS
      WRITE(6,25)
   25 FORMAT(2X,'ENTER LENGTH OF SEASON VIA FORMAT I2.')
      READ(5,26)LSEAS
26    FORMAT(I2)
  202 IF(ANS.NE.Y)LSEAS=1
      IF(ANS.NE.Y)IQS=0
      IF(ANS.NE.Y)IPS=0
      IF(ANS.NE.Y)NDIFS=0
      WRITE(6,201)
  201 FORMAT(/,2X,'ENTER NONSEASONAL DATA AS REQUESTED:',/)
      WRITE(6,12)
   12 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL DIFFERENCES.')
      READ(5,13)NDIFNS
   13 FORMAT(I1)
      WRITE(6,20)
   20 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.')
      READ(5,21)IP
   21 FORMAT(I1)
      WRITE(6,23)
   23 FORMAT(2X,'ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.')
      READ(5,21)IQ
C
C        INPUT YOUR PARAMETER ESTIMATES
C
    5 WRITE(6,30)
   30 FORMAT(/,2X,'NOW INPUT YOUR PARAMETER ESTIMATES:',/)
      WRITE(6,31)
   31 FORMAT(/,2X,'ENTER MA CONSTANT TERM, THETA0.')
      READ(5,52)PMAC
      IF(IP.EQ.0)GO TO 400
      DO 40 I=1,IP
      WRITE(6,41)I
   41 FORMAT(2X,'ENTER NON-SEASONAL AR PARAMETER PHI(',I1,').')
      READ(5,42)PHI(I)
```

```
   42 FORMAT(F15.6)
   40 CONTINUE
  400 IF(IPS.EQ.0)GO TO 500
      DO 50 J=1,IPS
      WRITE(6,51)J
   51 FORMAT(2X,'ENTER SEASONAL AR PARAMETER PHIS(',I1,').')
      READ(5,52)PHIS(J)
   52 FORMAT(F15.6)
   50 CONTINUE
  500 IF(IQ.EQ.0)GO TO 600
      DO 60 K=1,IQ
      WRITE(6,61)K
   61 FORMAT(2X,'ENTER NON-SEASONAL MA PARAMETER THETA(',I1,').')
      READ(5,62)THETA(K)
   62 FORMAT(F15.6)
   60 CONTINUE
  600 IF(IQS.EQ.0)GO TO 700
      DO 70 L=1,IQS
      WRITE(6,71)L
   71 FORMAT(2X,'ENTER SEASONAL MA PARAMETER THETAS(',I1,').')
      READ(5,72)THETAS(L)
   72 FORMAT(F15.6)
   70 CONTINUE
  700 WRITE(6,802)
  802 FORMAT(2X,'ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.')
      READ(5,801)ILT
  801 FORMAT(I2)
      WRITE(6,803)
  803 FORMAT(2X,'ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.')
      READ(5,806)LP
  806 FORMAT(I3)
      WRITE(6,8035)
 8035 FORMAT(2X,'ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.')
      READ(5,806)IFC
      WRITE(6,804)
  804 FORMAT(2X,'ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.')
      READ(5,805)ALPHA
  805 FORMAT(F15.6)
C
C
C
C         HERE, 1 IS ADDED TO THE NUMBER OF PARAMETERS SO THAT
C         THE "1" TERMS IN THE POLYNOMIALS OF BACKWARD DIFFERENCE
C         OPERATORS CAN BE ACCOUNTED FOR IN THE EXPANSION.
C
      IPT=IP+1
      IPST=IPS+1
      IQ1=IQ+1
      IQST=IQS+1
C
C         SHIFT THE ORIGIN ON THE PARAMETER VECTORS, AND
C         ASSIGN THEM TO TEMPORARY VECTORS.
C
      IF(IP.EQ.0)GO TO 111
      DO 15 MM=1,IP
      MM1=MM+1
      PHIT(MM1)=PHI(MM)
   15 CONTINUE
  111 IF(IPS.EQ.0)GO TO 112
      DO 16 MMM=1,IPS
      MMM1=MMM+1
      PHIST(MMM1)=PHIS(MMM)
   16 CONTINUE
  112 IF(IQ.EQ.0)GO TO 113
      DO 17 LL=1,IQ
      LL1=LL+1
      THETAT(LL1)=THETA(LL)
   17 CONTINUE
  113 IF(IQS.EQ.0)GO TO 114
      DO 18 LLL=1,IQS
```

```
      LLL1=LLL+1
      THEST(LLL1)=THETAS(LLL)
   18 CONTINUE
  114 PHIT(1)=1.0
      PHIST(1)=1.0
      THETAT(1)=1.0
      THEST(1)=1.0
C
C         UNRAVEL THE AR SIDE OF THE GENERAL MODEL:
C         KAR WILL KEEP TRACK OF THE NUMBER OF NON-ZERO
C         ELEMENTS OF THE PI VECTOR OF PARAMETERS.
C
      KAR=0
      DO 200 J=1,IPST
      DO 100 I=1,IPT
      KAR=KAR+1
      K=(I-1) + (J-1)*LSEAS
      INDAR(KAR)=K
      PI(KAR)=0.0
      PI(KAR) = PHIT(I)*PHIST(J)
      IF(((J.EQ.1).AND.(I.EQ.1)).OR.((J.GT.1).AND.(I.GT.1)))PI(KAR)=
     1-PI(KAR)
  100 CONTINUE
  200 CONTINUE
C
C         NOW UNRAVEL THE MA SIDE OF THE MODEL, FORMING THE
C         NON-ZERO ELEMENTS OF THE GAMMA VECTOR.
C
      KMA=0
      DO 300 JJ=1,ICST
      DO 401 II=1,IQT
      KMA=KMA+1
      KK=(II-1) + (JJ-1)*LSEAS
      INDMA(KMA)=KK
      GAMMA(KMA)=0.0
      GAMMA(KMA)=THETAT(II)*THEST(JJ)
      IF(((JJ.EQ.1).AND.(II.EQ.1)).OR.((JJ.GT.1).AND.(II.GT.1)))GAMMA(KM
     1A)=-GAMMA(KMA)
  401 CONTINUE
  300 CONTINUE
C
C         NOW, PUT THE PI AND GAMMA VECTORS INTO THE
C         LENGTHENED FORM NECESSARY TO ADD IN THE DIFFERENCING.
C
      LARVEC=IP+IPS*LSEAS+1
      LMAVEC=IQ+ICS*LSEAS+1
      DO 120 I=1,LARVEC
      PINEW(I)=0.0
  120 CONTINUE
      DO 121 I=1,LMAVEC
      GAMNEW(I)=0.0
  121 CONTINUE
      PINEW(1)=-1.0
      IF((IP.EQ.0).AND.(IPS.EQ.0))GO TO 224
      DO 122 I=2,KAR
      IND=INDAR(I)+1
      PINEW(IND)=PI(I)
  122 CONTINUE
  224 GAMNEW(1)=-1.0
      IF((IQ.EQ.0).AND.(ICS.EQ.0))GO TO 225
      DO 123 J=2,KMA
      IND1=INDMA(J)+1
      GAMNEW(IND1)=GAMMA(J)
  123 CONTINUE
      DO 131 K=2,LMAVEC
      K1=K-1
      PMAS(K1)=GAMNEW(K)
  131 CONTINUE
C
C         NOW, CRANK THE DIFFERENCES INTO THE AR SIDE OF THE MODEL.
```

```
C
  225 IFLAG=0
      LNEW = LSEAS
      IF((NDIFNS.EQ.0).AND.(NDIFS.EQ.0))GO TO 226
      IPP=IP+LSEAS*IPS
      ILIM=NDIFS
      II=IPP+2
      III=IPP+LSEAS*NDIFS+NDIFNS
      DO 124 I=II,III
      PINEW(I)=0.0
  124 CONTINUE
      IF(ILIM.LE.0)GO TO 2260
  125 DO 126 J=1,ILIM
      JMIN=IPP+2
      IF(JMIN.LE.LNEW*J)JMIN=LNEW*J+1
      JJ=IPP+LNEW+2
      JNUM=JJ-JMIN
      IF(JNUM.LE.0)GO TO 2270
      DO 127 J1=1,JNUM
      JJ=JJ-1
      PINEW(JJ) = -PINEW(JJ-LNEW)
  127 CONTINUE
 2270 JNUM = IPP-LNEW+1
      IF(JNUM.LE.0)GO TO 2280
      DO 128 J2=1,JNUM
      JJ=IPP+2-J2
      PINEW(JJ) = PINEW(JJ) - PINEW(JJ-LNEW)
  128 CONTINUE
 2280 IPP = IPP+LNEW
  126 CONTINUE
 2260 LNEW = 1
      ILIM=NDIFNS
      IFLAG=IFLAG+1
      IF(IFLAG.LT.2)GO TO 125
C
      LENGTH = IP+NDIFNS+LSEAS*(NDIFS+IPS)+1
      DO 129 I=2,LENGTH
      I1=I-1
      ARPS(I1)=PINEW(I)
  129 CONTINUE
      LARVEC = LENGTH
      GO TO 1978
  226 DO 130 I=2,LARVEC
      IJ=I-1
      ARPS(IJ)=PINEW(I)
  130 CONTINUE
C
C         COLLECT INPUTS FOR FTCAST ROUTINE.
C
 1978 LV(1)=IFC
      LV(2)=LARVEC-1
      LV(3)=LMAVEC-1
      LV(4)=0
      LV(5)=ILT
      CALL FTCAST(WVEC,ARPS,PMAS,PMAC,ALPHA,LV,DARPS,FCST,WNV,IER)
C
      SIGLEV=(1.0-ALPHA)*100.0
C
C
C         PERFORM UNTRANSFORMING OPERATIONS ON THE FORECASTS,
C         THE CONFIDENCE LIMITS, AND THE WVEC ITSELF.
C
      WRITE(6,8000)
 8000 FORMAT(/,2X,'WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?')
      READ(6,8001)ANS
 8001 FORMAT(A1)
      IF(ANS.NE.Y)GO TO 999
  888 READ(7,701)L,SHIFT,SCALE,P,FACTOR
  701 FORMAT(I1,4E15.6)
      IF(L.EQ.0)GO TO 702
C         UNTRANSFORM FOR POWER TRANSFORM
```

```
      C=1.0/P
      DO 703 I=LP,N
      WVEC(I)=((WVEC(I)**Q+FACTOR)/SCALE)+SHIFT
  703 CONTINUE
      DO 704 K=1,ILT
      IF(FCST(2,K).LE.0)GO TO 7045
      FCST(2,K)=((FCST(2,K)**Q+FACTOR)/SCALE)+SHIFT
      IF(FCST(3,K).LE.0)GO TO 7045
      FCST(3,K)=((FCST(3,K)**Q+FACTOR)/SCALE)+SHIFT
  704 CONTINUE
      GO TO 995
 7045 ILT=K
      WRITE(6,7046)K
 7046 FORMAT(/,2X,'A FORECAST VALUE WAS NEGATIVE; NO FORECAST BEYOND LEA
     1D TIME',/,2X,I3,' WILL BE PLOTTED.')
      GO TO 995
C        UNTRANSFORM FOR LOGGED DATA
  702 DO 705 I=LP,N
      WVEC(I)=((EXP(WVEC(I))+FACTOR)/SCALE)+SHIFT
  705 CONTINUE
      DO 706 K=1,ILT
      IF(FCST(2,K).LE.0)GO TO 7065
      FCST(2,K)=((EXP(FCST(2,K))+FACTOR)/SCALE)+SHIFT
      IF(FCST(3,K).LE.0)GO TO 7065
      FCST(3,K)=((EXP(FCST(3,K))+FACTOR)/SCALE)+SHIFT
  706 CONTINUE
      GO TO 995
 7065 ILT=K
      WRITE(6,7046)K
  995 DO 132 I=1,ILT
      FL(I)=FCST(2,I)-FCST(3,I)
      FU(I)=FCST(2,I)+FCST(3,I)
  132 CONTINUE
      WRITE(6,7075)
 7075 FORMAT(/,2X,'DO YOU WANT BASIC OUTPUT AT THE TERMINAL?')
      READ(5,7076)ANS
 7076 FORMAT(A1)
      IF(ANS.NE.Y)GO TO 999
      WRITE(6,775)
  775 FORMAT(/,2X,'THE LAST 10 WVEC VALUES:',/)
      ISTART=N-9
      WRITE(6,778)(WVEC(I),I=ISTART,N)
      WRITE(6,777)ILT
  777 FORMAT(/,2X,'THE ',I2,' FORECAST VALUES:',/)
      WRITE(6,778)(FCST(2,I),I=1,ILT)
  778 FORMAT(5E14.6)
      WRITE(6,779)ILT
  779 FORMAT(/,2X,'THE ',I2,' UPPER FORECAST CONFIDENCE LIMITS:',/)
      WRITE(6,778)(FU(I),I=1,ILT)
      WRITE(6,780)ALPHA
  780 FORMAT(/,2X,'ALPHA FOR THE CONFIDENCE LIMITS IS: ',F5.3)
C
C        PUT INFO INTO CORRECT FORM AND DO PLOTS.
C
  999 L=IFO
      IF(LP.LT.1)LP=1
      IF(LP.GT.L)LP=L
      VMAX=WVEC(LP)
      GMIN=WVEC(LP)
      DO 133 I=LP,L
      J=I-LP+1
      W(J)=WVEC(I)
      T(J)=WVEC(I)
      V(J)=WVEC(I)
      IF(V(J).GT.VMAX)VMAX=V(J)
      G(J)=WVEC(I)
      IF(G(J).LT.GMIN)GMIN=G(J)
      X(J)=I
  133 CONTINUE
      KK=LV(5)
```

```
      DO 134 I=1,KK
      JJ=J+I
      W(JJ)=FCST(2,I)
      T(JJ)=FCST(2,I)
      V(JJ)=FU(I)
      IF(V(JJ).GT.VMAX)VMAX=V(JJ)
      G(JJ)=FL(I)
      IF(G(JJ).LT.GMIN)GMIN=G(JJ)
      X(JJ)=L+I
  134 CONTINUE
      IF(N.LE.L)GO TO 135
      KKK=L+1
      DO 136 I=KKK,N
      II=I-LP+1
      W(II)=WVEC(I)
  136 CONTINUE
  135 RANGE(1)=L+KK
      RANGE(2)=LP
      RANGE(3)=VMAX
      RANGE(4)=GMIN
      NUM=RANGE(1)-LP+1
      WRITE(8,137)
  137 FORMAT('1')
      CALL UTPLT8(X,V,NUM,RANGE,1,1)
      CALL UTPLT8(X,G,NUM,RANGE,1,2)
      CALL UTPLT8(X,T,NUM,RANGE,1,2)
      CALL UTPLT8(X,W,NUM,RANGE,1,3)
      WRITE(8,138)
  138 FORMAT(14X,'ORIGINAL AND FORECASTED TIME SERIES.')
      WRITE(8,690)
  690 FORMAT(///,14X,'.    UPPER CONFIDENCE INTERVAL',
     1/,14X,'+    LOWER CONFIDENCE INTERVAL',
     2/,14X,'*    FORECASTS',
     3/,14X,'X    ACTUAL DATA POINTS')
C
      WRITE(8,791)
  791 FORMAT('1',/,2X,'FORECAST VALUES:',//)
      WRITE(8,792)(FCST(2,I),I=1,ILT)
  792 FORMAT(5F15.6)
      WRITE(8,793)
  793 FORMAT(/,2X,'UPPER CONFIDENCE LIMITS:',//)
      WRITE(8,792)(FU(I),I=1,ILT)
      WRITE(8,794)
  794 FORMAT(/,2X,'LOWER CONFIDENCE LIMITS:',//)
      WRITE(8,792)(FL(I),I=1,ILT)
      WRITE(8,795)SIGLEV
  795 FORMAT(/,2X,'SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS:',F7.3)
      WRITE(8,796)IFO
  796 FORMAT(/,2X,'FORECAST ORIGIN:',I3)
      WRITE(8,798)ILT
  798 FORMAT(/,2X,'MAXIMUM FORECAST LEAD TIME:',I3)
      STOP
      END
```

```
      DIMENSION PHI(8),A(9),CNORM(8)
      COMPLEX C(8)
      DATA Y/'Y'/

      WRITE(6,3)
    3 FORMAT(2X,'SOLVES FOR ROOTS OF CHARACTERISTIC EQUATION.'/)
      WRITE(6,1)
    1 FORMAT(2X,'ENTER NO. OF AR PARAMETERS (UNDIFF. FORM).')
      READ(5,2) NDEG
    2 FORMAT(I1)
      WRITE(6,12)
   12 FORMAT(4X,'ENTER AUTOREGRESSIVE PARAMETERS:')
      J=NDEG+1
      A(J)=1.0
      DO 10 I=1,NDEG
      WRITE(6,4) I
    4 FORMAT(2X,'ENTER PHI(',I1,').')
      READ(5,5) PHI(I)
    5 FORMAT(F15.6)
      K=J-I
   10 A(K)=-PHI(I)
      CALL ZPOLR(A,NDEG,C,IER)
   20 FORMAT('0',2X,'THE ',I1,' ROOTS OF CHARACTERISTIC EQ. AND NORMS',
     *' ARE:'/(3X,3F10.3))
      DO 37 J=1,NDEG
      TEMP = C(J)*CONJG(C(J))
   37 CNORM(J)=SQRT(TEMP)
      WRITE(6,20) NDEG,(C(I),CNORM(I),I=1,NDEG)
      STOP
      END
```

```
      DIMENSION PHI(10),THETA(10),START(10),W(999),WA(999)
      REAL*8 SEED
      DATA IC1/'Y'/,IP4/'V'/,IP5/'C'/
      DATA PHI/6*0.0/,THETA/6*0.0/,START/6*0.0/,CONS/0.0/
      WRITE(6,301)
  301 FORMAT(1X,'ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).')
   60 READ(5,777) SEED
  777 FORMAT(F15.12)
      SEED = SEED * 1000000000.
      ISEED = SEED
  302 FORMAT(G15.6)
   70 WRITE(6,71)
   71 FORMAT(' ENTER NO. OF AR PARAMETERS, IP (UNDIFF. FORM)')
      READ(5,72) IP
   72 FORMAT(I1)
      WRITE(6,360)
  360 FORMAT('  ENTER NO. OF MA PARAMETERS, IQ.')
      READ(5,72) IQ
      WRITE(6,361)
  361 FORMAT(' ENTER LW, THE LENGTH OF THE TIME SERIES VIA I3.')
      READ(5,307) LW
  320 WRITE(6,304)  IP,IQ,LW
  304 FORMAT(1X,'IP= ',I1,3X,'IQ= ',I1,3X,'LW = ',I3)
      WRITE(6,306)
      READ(5,395) IANS
  395 FORMAT(A1)
      IF(IANS.EQ.IC1) GO TO 401
      WRITE(6,306)
  306 FORMAT(1X,'DO YOU WISH TO CHANGE LW?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 310
      WRITE(6,404)
      READ(5,307) LW
  307 FORMAT(I3)
      GO TO 320
  310 WRITE(6,311)
  311 FORMAT(1X,'DO YOU WANT TO CHANGE IP?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 644
      WRITE(6,404)
      READ(5,72) IP
  644 WRITE(6,645)
  645 FORMAT(' DO YOU WANT TO CHANGE IQ?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 401
      WRITE(6,404)
      READ(5,72) IQ
      GO TO 320
  404 FORMAT(1X,'ENTER NEW VALUE')
  401 WRITE(1,304) IP,IQ,LW
      WRITE(6,203)
  203 FORMAT(1X,'ENTER ERROR VARIANCE, VAR.')
      READ(5,302) VAR
      WRITE(6,204)
  204 FORMAT(1X,'DO YOU WANT A NONZERO CONSTANT TERM?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 331
      WRITE(6,205)
  205 FORMAT(1X,'ENTER CONSTANT TERM.')
      READ(5,302) CONS
  331 WRITE(6,402) VAR,CONS
  402 FORMAT(1X,'ERROR VARIANCE=',G15.6,5X,'CONSTANT TERM=',G15.6)
      WRITE(6,206)
      READ(5,395) IANS
      IF(IANS.EQ.IC1) GO TO 531
      WRITE(6,403)
  403 FORMAT(1X,'WHICH VARIABLE TO CHANGE, VARIANCE OR CONSTANT?')
      READ(5,395) IANS
      WRITE(6,404)
      READ(5,302) XANS
```

```
      IF(IANS.EQ.IP4) VAR=XANS
      IF(IANS.EQ.IP5) CONS=XANS
      GO TO 331
  531 WRITE(1,402) VAR,CONS
      IF(IP.LE.0) GO TO 631
      DO 502 I=1,IP
      WRITE(6,514) I
  514 FORMAT(1X,'ENTER AUTOREGRESSIVE PARAMETER PHI(',I1,').')
  502 READ(5,302) PHI(I)
  504 WRITE(6,505) (PHI(I),I=1,IP)
  505 FORMAT(1X,'AR PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,206)
  206 FORMAT(1X,'ARE THESE OK?')
      READ(5,355) IANS
      IF(IANS.EQ.IC1) GO TO 600
      WRITE(6,207)
  207 FORMAT(1X,'ENTER INDEX, I, FOR VALUE YOU WANT TO CHANGE.')
      READ(5,71) I
      WRITE(6,404)
      READ(5,302) PHI(I)
      GO TO 504
  600 WRITE(1,505) (PHI(I),I=1,IP)
  631 IF(IQ.LE.0) GO TO 731
      DO 602 I=1,IQ
      WRITE(6,601) I
  601 FORMAT(1X,'ENTER MOVING AVERAGE PARAMETER THETA(',I1,').')
  602 READ(5,302) THETA(I)
  610 WRITE(6,603) (THETA(I),I=1,IQ)
  603 FORMAT(1X,'MA PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,206)
      READ(5,355) IANS
      IF(IANS.EQ.IC1) GO TO 700
      WRITE(6,207)
      READ(5,71) I
      WRITE(6,404)
      READ(5,302) THETA(I)
      GO TO 610
  700 WRITE(1,603) (THETA(I),I=1,IQ)
  731 IF(IP.LE.0) GO TO 831
      DO 702 I=1,IP
      WRITE(6,701) I
  701 FORMAT(1X,'ENTER INITIAL STARTING VALUE START(',I1,').')
  702 READ(5,302) START(I)
  710 WRITE(6,703) (START(I),I=1,IP)
  703 FORMAT(1X,'START VALUES ARE',4(2X,F11.3))
      WRITE(6,206)
      READ(5,355) IANS
      IF(IANS.EQ.IC1) GO TO 800
      WRITE(6,207)
      READ(5,71) I
      WRITE(6,404)
      READ(5,302) START(I)
      GO TO 710
  800 WRITE(1,703) (START(I), I=1,IP)
  831 CALL FTGEN1(PHI,THETA,CONS,START,VAR,ISEED,IP,IQ,LW,W,WA)
      WRITE(1,801)
  801 FORMAT(/10X,'GENERATED TIME SERIES')
      WRITE(1,802) (W(I),I=1,LW)
  802 FORMAT(5E15.6)
      WRITE(2,307) LW
      WRITE(2,802) (W(I),I=1,LW)
      WRITE(6,853)
  853 FORMAT(1X,'YOUR TIME SERIES HAS BEEN GENERATED.'/
     *' IT HAS BEEN PRINTED OFFLINE.'/
     *' YOU MAY PICK IT UP IN ROOM I-140 UNDER YOUR USER ID NUMBER.'/
     *' THE TIME SERIES IS IN FILE FT02F001 IF YOU WANT TO SEE IT.')
      STOP
      END
```

```
      DIMENSION  Z(999),ARPS(10),PMAS(10),SIM(999),START(10)
      REAL*8     WA(1558)
      DATA  Y/'Y'/
      DO 1 I=1,10
      ARPS(I)=0.
    1 PMAS(I)=0.
      READ(2,200)  L
  200 FORMAT(I3)
      READ(2,201) (Z(I),I=1,L)
  201 FORMAT(5E15.6)
      WRITE(6,600)
      READ(5,500) IP
  600 FORMAT(2X,'ENTER NUMBER OF AR PARAMETERS (UNDIFFERENCED FORM)')
  500 FORMAT(I1)
      IF(IP.LE.0) GO TO 53
   51 DO 52 I=1,IP
      WRITE(6,314) I
  314 FORMAT(2X,'ENTER ESTIMATED AR PARAMETER PHI(',I1,').')
   52 READ(5,302)  ARPS(I)
  302 FORMAT(F15.6)
      WRITE(6,505)  (ARPS(I),I=1,IP)
  505 FORMAT(2X,'AR PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,206)
  206 FORMAT(2X,'ARE THESE OK?')
      READ(5,395) ANS
  395 FORMAT(A1)
      IF(ANS.EQ.Y) GO TO 53
      GO TO 51
   53 WRITE(6,601)
  601 FORMAT(2X,'ENTER  NUMBER OF MA PARAMETERS')
      READ(5,501) IQ
  501 FORMAT(I1)
      IF(IQ.LE.0) GO TO 55
   56 DO 402 I=1,IQ
      WRITE(6,401) I
  401 FORMAT(2X,'ENTER MA PARAMETER THETA(',I1,').')
  402 READ(5,302)  PMAS(I)
      WRITE(6,403)  (PMAS(I),I=1,IQ)
  403 FORMAT(2X,'MA PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,406)
  406 FORMAT(2X,'ARE THESE OK?')
      READ(5,395) ANS
      IF(ANS.EQ.Y) GO TO 55
      GO TO 56
   55 WRITE(6,704)
  704 FORMAT(2X,'ENTER OVERALL MA CONSTANT')
      READ(5,705)  FMAC
  705 FORMAT(E15.6)
      WRITE(6,602)
  602 FORMAT(2X,'ENTER ESTIMATED WHITE NOISE VAR')
      READ(5,502) WNV
  502 FORMAT(F15.6)
  400 WRITE(6,411)
  411 FORMAT(2X,'DO YOU WANT STARTING VALUES TO BE THE LAST VALUES',/
     *'   OF THE ACTUAL SERIES?')
      READ(5,395) ANS
      IF(ANS.EQ.Y) GO TO 414
      WRITE(6,1055)
 1055 FORMAT(2X,'DO YOU WANT TO SELECT INDEX OF TIME SERIES',/
     *'VALUE WHERE SIMULATION WILL BEGIN?')
      READ(5,395) ANS
      IF(ANS.EQ.Y) GO TO 2000
      DO 2001 I = 1,IP
      WRITE(6,2002) I
 2002 FORMAT(2X,'ENTER START(',I1,')')
      READ(5,2003) START(I)
 2003 FORMAT(G16.5)
 2001 CONTINUE
      GO TO 420
 2000 WRITE(6,1056)
```

```
 1056 FORMAT(2X,'ENTER INDEX OF STARTING VALUE VIA I3.')
      READ(5,200) K
      IF(IP.EQ.0) GO TO 416
      IF(K-1+IP.GT.L) GO TO 417
      DO 413 I=1,IP
  413 START(I)=Z(K-1+I)
      GO TO 419
  414 IF(IP.EQ.0) GO TO 416
      DO 415 I=1,IP
  415 START(I)=Z(L-IP+I)
      GO TO 419
  416 START(1)=Z(K)
      GO TO 419
  417 WRITE(6,418)
  418 FORMAT(2X,'INVALID STARTING VALUE. SEE IF ANY STARTING VALUE WAS P
     *ICKED OF OUTSIDE OF RANGE OF INPUT DATA, VECTOR Z(I)')
      GO TO 400
  419 DO 420 I=1,IP
  420 WRITE(6,421) I,START(I)
  421 FORMAT(2X,'START(',I1,')=',F15.6)
      WRITE(6,422)
  422 FORMAT(2X,'STARTING VALUE(S) OK?')
      READ(5,395) ANS
      IF(ANS.NE.Y) GO TO 400
      WRITE(6,603)
  603 FORMAT(2X,'ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).')
      READ(5,503) SEED
  503 FORMAT(F15.12)
      SEED = SEED * 1000000000.
      ISEED = SEED
      WRITE(6,604)
  604 FORMAT(2X,'ENTER NUMBER OF VALUES YOU WANT TO SIMULATE VIA I3.')
      READ(5,200) LW
      JJ=20
      IF(LW.LT.20) JJ=LW
      CALL FTGEN1(ARPS,PMAS,PMAC,START,WNV,ISEED,IP,IQ,LW,SIM,WA)
      WRITE(3,60) LW
   60 FORMAT(I3)
      WRITE(3,61) (SIM(I),I=1,LW)
   61 FORMAT(5E15.6)
      WRITE(6,3010)
 3010 FORMAT(2X,'DO YOU WANT A PRINTOUT OF THE FIRST 20 VALUES?')
      READ(5,395) ANS
      IF(ANS.NE.Y) GO TO 125
      WRITE(6,608) (SIM(I),I=1,JJ)
  608 FORMAT(2X,'SIMULATED VALUES ARE:'/(5F14.5))
  125 CONTINUE
      IF(IER.EQ.0) GO TO 610
      WRITE(6,607) IER
  607 FORMAT(2X,'ERROR PARAMETER= ',I3,' SEE EXPLANATION IN SUBROUTINE F
     *TGEN1 (IMSL).')
  610 STOP
      END
```

```
      SUBROUTINE FTMAPS(ACV,ARPS,IP,IQ,PMAS,WNV,WA,IER)                 FTM00010
      DIMENSION ACV(1),ARPS(1),PMAS(1),WA(1),EPS(6)                     FTM00020
      DOUBLE PRECISION WA,EPS,SUM,TOL,EPSMAX                            FTM00030
      DATA ZERO,ONEM,TOL,NSIG,ITMAX,EPSMAX/0.,-1.,.001,3,100,0.0D0/     FTM00040
      IER=0                                                             FTM00050
      IQP1=IQ+1                                                         FTM00060
      IF(IP.GT.0)GO TO 10                                               FTM00070
      DO 5 I=1,IQP1                                                     FTM00080
    5 WA(I)=ACV(I)                                                      FTM00090
      GO TO 30                                                          FTM00100
   10 IPP1=IP+1                                                         FTM00110
      DO 25 I=1,IQP1                                                    FTM00120
      IM=I                                                              FTM00130
      WA(I)=ZERO                                                        FTM00140
      AJ=ONEM                                                           FTM00150
      DO 20 J=1,IPP1                                                    FTM00160
      IF(J.GT.1)AJ=ARPS(J-1)                                            FTM00170
      AK=ONEM                                                           FTM00180
      DO 15 K=1,IPP1                                                    FTM00190
      L=IABS(IM-K) + 1                                                  FTM00200
      IF(K.GT.1)AK=ARPS(K-1)                                            FTM00210
   15 WA(I)=WA(I) + (AJ*AK*ACV(L))                                      FTM00220
   20 IM=IM + 1                                                         FTM00230
   25 CONTINUE                                                          FTM00240
   30 IQP2=IQP1 + 1                                                     FTM00250
      IF(WA(1).LE.ZERO)GO TO 60                                         FTM00260
      WA(IQP2)=WA(1)                                                    FTM00270
      IF(WA(IQP2).LE.0)GO TO 75                                         FTM00280
      II=IQP2+1                                                         FTM00290
      III=IQ+IQ+2                                                       FTM00300
      DO 35 I=II,III                                                    FTM00310
   35 WA(I)=ZERO                                                        FTM00320
      DO 70 I=1,ITMAX                                                   FTM00330
      DO 45 J=1,IQ                                                      FTM00340
      SUM=-WA(J+1)/WA(IQP2)                                             FTM00350
      IF((IQ-J).LE.0)GO TO 51                                           FTM00360
      IIII=IQ-J                                                         FTM00370
      DO 50 K=1,IIII                                                    FTM00380
   50 SUM = SUM + WA(IQP2+K)*WA(IQP2+K+J)                               FTM00390
   51 EPS(J) = DABS(WA(IQP2+J)-SUM)                                     FTM00400
   45 WA(IQP2+J)=SUM                                                    FTM00410
      SUM=1.0D0                                                         FTM00420
      EPSMAX=0.0D0                                                      FTM00430
      DO 60 J=1,IQ                                                      FTM00440
      SUM = SUM + WA(IQP2+J)*WA(IQP2+J)                                 FTM00450
   60 IF(EPS(J).GT.EPSMAX)EPSMAX=EPS(J)                                 FTM00460
      EPS(IQ+1)=DABS(WA(IQP2)-WA(1)/SUM)                                FTM00470
      WA(IQP2)= WA(1)/SUM                                               FTM00480
      EPSMAX = DMAX1(EPSMAX,EPS(IQ+1))                                  FTM00490
      IF(EPSMAX.LT.TOL)GO TO 71                                         FTM00500
   70 CONTINUE                                                          FTM00510
      IER=1                                                             FTM00520
   71 IF(IER.EQ.1)WRITE(6,100)                                          FTM00530
      GO TO 200                                                         FTM00540
   75 WRITE(6,101)                                                      FTM00550
  100 FORMAT(/,2X,'CONVERGENCE WAS NOT REACHED IN 100 ITERATIONS.')     FTM00560
  101 FORMAT(/,2X,'VARIANCE IS LE 0; NO OUTPUT OBTAINED.')              FTM00570
      GO TO 9005                                                        FTM00580
  200 WNV = WA(IQP2)                                                    FTM00590
      DO 225 I=1,IQ                                                     FTM00600
  225 PMAS(I) = WA(IQP2+I)                                              FTM00610
 9005 RETURN                                                            FTM00620
      END                                                               FTM00630
```

```
      FUNCTION FTFUNC(X,I,PAR)
      DIMENSION X(1),PAR(1)
      DOUBLE PRECISION X,PAR,FTFUNC
      COMMON /FTCOMN/IOP1
      IM1=I-1
      IF(IM1.EQ.0)GO TO 6
      FTFUNC=-X(IM1)
      GO TO 7
    6 FTFUNC=1.0
    7 J=IOP1-1
      IF(J)8,9,5
    5 DO 10 K=1,J
      L=K+IM1
   10 FTFUNC = FTFUNC + X(K)*X(L)
    9 FTFUNC = FTFUNC*X(IOP1)-PAR(I)
    8 RETURN
      END
```

APPENDIX E

LISTING OF DATA SETS RESIDING IN THE TIME SERIES EDITOR

This appendix contains listings of the data sets now residing in the Time Series Editor. The data consists of Box and Jenkins' [Ref. 4] time series C [Ref. 4, p. 528] and time series G [Ref. 4, p. 531], as well as a data set containing monthly Monterey, California, rainfall data from January 1931 through December 1976 .

09/16/78 17.47.08

FILE: SERC FT02F001 P1 N P S PAGE 001

226

26.6	27.0	27.1	27.1	27.1
27.1	26.9	26.8	26.7	26.4
26.0	25.8	25.6	25.2	25.0
24.6	24.2	24.0	23.7	23.4
23.1	22.9	22.8	22.7	22.6
22.4	22.2	22.0	21.8	21.4
20.9	20.3	19.7	19.4	19.3
19.2	19.1	19.0	18.9	18.9
19.2	19.3	19.3	19.4	19.5
19.6	19.6	19.6	19.6	19.6
19.7	19.9	20.0	20.1	20.2
20.3	20.6	21.6	21.9	21.7
21.3	21.2	21.4	21.7	22.2
23.0	23.8	24.6	25.1	25.6
25.8	26.1	26.3	26.3	26.2
26.0	25.6	25.6	25.4	25.2
24.9	24.7	24.5	24.4	24.4
24.4	24.4	24.4	24.3	24.4
24.4	24.4	24.4	24.4	24.5
24.5	24.4	24.3	24.2	24.2
24.0	23.9	23.7	23.6	23.5
23.5	23.5	23.5	23.5	23.7
23.8	23.8	23.9	23.9	23.8
23.7	23.6	23.4	23.2	23.0
22.8	22.6	22.4	22.0	21.6
21.3	21.2	21.2	21.1	21.0
20.9	21.0	21.0	21.1	21.2
21.1	20.9	20.8	20.8	20.8
20.8	20.9	20.8	20.8	20.7
20.7	20.8	20.9	21.2	21.4
21.7	21.8	21.9	22.2	22.5
22.8	23.1	23.4	23.8	24.1
24.6	24.9	24.9	25.1	25.0
25.0	25.0	25.0	24.9	24.8
24.7	24.6	24.5	24.5	24.5
24.5	24.5	24.5	24.5	24.4
24.4	24.2	24.2	24.1	24.1
24.0	24.0	24.0	23.9	23.8
23.8	23.7	23.7	23.6	23.7
23.6	23.6	23.6	23.5	23.5
23.4	23.3	23.3	23.3	23.4
23.4	23.3	23.2	23.3	23.3
23.2	23.1	22.9	22.8	22.6
22.4	22.2	21.8	21.3	20.8
20.2	19.7	19.3	19.1	19.0
18.8				

144

112.0	118.0	132.0	129.0	121.0
135.0	148.0	148.0	136.0	119.0
104.0	118.0	115.0	126.0	141.0
135.0	125.0	149.0	170.0	170.0
158.0	133.0	114.0	140.0	145.0
150.0	178.0	163.0	172.0	178.0
155.0	199.0	184.0	162.0	146.0
166.0	171.0	180.0	193.0	181.0
183.0	218.0	230.0	242.0	209.0
191.0	172.0	194.0	196.0	196.0
236.0	235.0	229.0	243.0	264.0
272.0	237.0	211.0	180.0	201.0
204.0	188.0	235.0	227.0	234.0
264.0	302.0	293.0	259.0	229.0
203.0	229.0	242.0	233.0	267.0
269.0	270.0	315.0	364.0	347.0
312.0	274.0	237.0	278.0	284.0
277.0	317.0	313.0	318.0	374.0
413.0	405.0	355.0	306.0	271.0
306.0	315.0	301.0	356.0	348.0
355.0	422.0	465.0	467.0	404.0
347.0	305.0	336.0	340.0	318.0
362.0	348.0	363.0	435.0	491.0
505.0	404.0	359.0	310.0	337.0
360.0	342.0	406.0	396.0	420.0
472.0	548.0	559.0	463.0	407.0
362.0	405.0	417.0	391.0	419.0
461.0	472.0	535.0	622.0	606.0
508.0	461.0	390.0	432.0	

54C

3.680000E00	3.290000E00	7.000000E-1	5.100000E-1	8.800000E-1
0.000000E0	0.000000E0	0.000000E0	0.000000E0	0.000000E0
3.600000E-1	2.410000E00	4.970000E00	7.300000E-1	1.410000E00
2.500000E-1	7.600000E-1	3.500000E-1	0.000000E00	0.000000E00
1.100000E-1	8.500000E-1	0.000000E00	3.240000E00	1.090000E00
3.920000E00	0.000000E00	2.600000E-1	3.900000E-1	7.430000E-1
0.000000E00	0.000000E00	4.500000E-1	4.300000E-1	2.740000E00
3.640000E00	6.590000E00	3.700000E-1	5.130000E00	4.190000E00
0.000000E00	0.000000E00	0.000000E00	5.300000E-1	0.000000E00
1.660000E00	1.000000E-1	9.300000E-1	3.190000E00	6.590000E00
1.310000E00	8.700000E-1	6.100000E-1	3.400000E-1	0.000000E00
0.000000E0	0.000000E0	1.080000E0	0.000000E0	4.560000E0
4.770000E00	5.740000E00	7.020000E00	5.800000E-1	0.000000E00
0.000000E00	0.000000E00	0.000000E00	0.000000E00	6.400000E-1
1.270000E0	4.600000E0	4.990000E0	7.590000E0	5.630000E0
2.250000E00	5.000000E-2	0.000000E00	1.800000E-1	0.000000E00
1.700000E-1	1.260000E00	7.700000E-1	2.090000E00	3.190000E00
1.620000E00	2.370000E00	2.800000E-1	6.300000E-1	7.000000E-2
0.000000E00	0.000000E00	1.300000E-1	7.500000E-1	4.800000E-1
1.470000E00	8.430000E00	8.200000E00	4.240000E00	7.200000E-1
1.300000E-1	0.000000E00	0.000000E00	0.000000E00	0.000000E00
0.000000E00	7.900000E-1	4.520000E00	6.150000E00	7.730000E00
5.500000E00	5.760000E00	4.700000E-1	4.000000E-2	0.000000E00
0.000000E00	0.000000E00	8.000000E-1	2.800000E-1	7.870000E00
3.480000E00	2.910000E00	2.430000E00	3.660000E00	7.900000E-1
0.000000E00	1.200000E-1	1.800000E-1	0.000000E00	1.130000E00
1.470000E00	9.700000E-1	3.050000E00	2.750000E00	4.240000E00
1.300000E00	1.000000E-1	0.000000E00	0.000000E00	6.000000E-2
2.000000E-2	6.200000E-1	4.200000E-1	3.830000E00	3.690000E00
6.080000E00	7.100000E-1	1.160000E00	8.300000E-1	2.400000E-1
1.000000E-1	1.000000E-1	0.000000E00	1.130000E00	4.650000E00
1.940000E00	9.800000E-1	3.180000E00	2.830000E00	4.300000E-1
3.000000E-1	1.100000E-1	0.000000E00	6.000000E-2	3.000000E-2
1.370000E0	1.400000E0	4.230000E0	1.080000E0	2.560000E0
3.000000E00	4.000000E-2	6.400000E-1	0.000000E00	0.000000E00
0.000000E00	1.500000E-1	2.600000E-1	4.310000E00	1.970000E00
4.400000E-1	1.130000E00	1.950000E00	3.300000E-1	2.100000E-1
1.200000E-1	0.000000E00	0.000000E00	0.000000E00	1.160000E00
4.700000E-1	1.940000E00	9.000000E-2	2.140000E00	4.610000E00
3.250000E00	4.000000E-1	1.700000E-1	0.000000E00	0.000000E00
0.000000E00	2.130000E00	3.500000E-1	3.200000E00	1.700000E00
2.640000E00	4.730000E00	8.000000E-2	4.200000E-1	5.000000E-2
8.000000E-2	1.700000E-1	0.000000E00	3.000000E-2	1.650000E00
1.370000E0	3.120000E0	1.740000E0	1.640000E0	1.470000E0
1.900000E-1	1.100000E-1	0.000000E00	7.000000E-2	9.000000E-2
1.760000E0	3.000000E0	2.370000E0	2.060000E0	2.150000E0
1.480000E00	1.060000E00	2.700000E-1	1.200000E-1	1.100000E-1
1.000000E-1	5.000000E-2	6.700000E-1	3.350000E00	6.040000E00
8.010000E00	2.110000E00	4.550000E00	1.100000E00	1.200000E-1
1.700000E-1	4.000000E-2	7.000000E-2	1.900000E-1	1.400000E-1
2.210000E00	5.040000E00	1.710000E00	3.410000E00	7.700000E-1
1.250000E00	5.700000E-1	2.200000E-1	0.000000E00	5.000000E-2
7.000000E-2	2.600000E-1	2.050000E00	3.100000E-1	3.330000E00
1.580000E00	4.410000E00	7.800000E-1	3.900000E-1	5.100000E-1
2.000000E-2	1.600000E-1	3.000000E-2	2.000000E-2	2.170000E00
2.820000E00	4.560000E00	1.560000E00	1.300000E-1	1.660000E00
5.600000E-1	5.000000E-2	6.000000E-2	1.000000E-1	5.000000E-2
4.000000E-2	1.650000E00	8.310000E00	4.820000E00	1.740000E00
1.800000E-1	1.560000E00	5.900000E-1	1.200000E-1	6.000000E-2
5.000000E-2	2.200000E-1	6.500000E-1	1.560000E00	7.700000E-1
4.320000E0	2.610000E0	1.890000E0	1.340000E0	2.640000E0
2.100000E-1	2.000000E-2	5.000000E-2	2.200000E-1	2.020000E00
8.500000E-1	3.380000E00	2.620000E00	4.620000E00	6.760000E00
3.980000E00	4.900000E-1	2.200000E-1	1.500000E-1	1.000000E-1
5.500000E-1	4.000000E-2	3.900000E-1	4.000000E-1	4.470000E00
5.630000E00	3.400000E-1	4.600000E-1	1.200000E-1	2.000000E-2
3.000000E-2	9.000000E-2	2.170000E00	3.000000E-2	0.000000E00
6.200000E-1	3.990000E00	3.270000E00	6.500000E-1	8.700000E-1
4.100000E-1	1.000000E-2	8.000000E-2	4.000000E-2	1.000000E-2

7.000000E-2	1.450000E00	6.400000E-1	1.840000E00	1.110000E00
2.420000E00	1.260000E00	7.500000E-1	4.000000E-2	4.000000E-2
1.600000E-1	1.400000E-1	1.000000E-1	2.030000E00	1.380000E00
2.230000E00	5.830000E00	2.400000E00	2.700000E-1	1.500000E-1
0.000000E00	1.300000E-1	2.800000E-1	8.000000E-2	1.360000E00
4.400000E-1	2.260000E00	3.830000E00	2.270000E00	4.320000E00
3.320000E00	6.500000E-1	5.000000E-2	1.100000E-1	4.000000E-2
5.700000E-1	1.360000E00	5.260000E00	5.400000E-1	3.190000E00
3.900000E-1	2.300000E00	1.000000E-1	6.900000E-1	1.900000E-1
1.900000E-1	3.300000E-1	5.000000E-2	1.060000E00	3.160000E00
5.570000E00	2.370000E00	9.300000E-1	2.430000E00	2.180000E00
1.400000E-1	6.000000E-2	6.000000E-2	1.900000E-1	1.000000E-2
1.600000E-1	6.250000E00	6.230000E00	3.050000E00	1.490000E00
5.100000E-1	1.700000E-1	1.400000E-1	1.900000E-1	3.200000E-1
2.000000E-1	4.100000E-1	1.400000E-1	4.690000E00	3.880000E00
5.750000E00	4.500000E-1	5.070000E00	6.810000E00	7.900000E-1
8.900000E-1	6.000000E-2	1.600000E-1	2.300000E-1	2.700000E-1
1.810000E0	2.060000E0	3.110000E0	1.350000E0	3.180000E0
7.200000E-1	2.900000E-1	4.000000E-2	0.000000E00	2.700000E-1
1.800000E-1	4.300000E-1	3.300000E00	2.750000E00	8.480000E00
7.860000E00	1.200000E00	2.490000E00	1.900000E-1	2.600000E-1
1.500000E-1	2.400000E-1	1.900000E-1	4.100000E-1	1.010000E00
2.800000E00	5.550000E00	3.020000E00	1.860000E00	4.300000E-1
8.000000E-2	3.200000E-1	5.000000E-2	1.900000E-1	4.000000E-2
5.400000E-1	7.440000E00	4.450000E00	8.700000E-1	6.400000E-1
1.940000E00	1.190000E00	5.800000E-1	5.000000E-2	1.100000E-1
1.700000E-1	3.500000E-1	1.700000E-1	1.550000E00	4.680000E00
1.000000E00	4.400000E-1	8.000000E-2	7.200000E-1	1.800000E-1
2.900000E-1	9.000000E-2	1.000000E-1	1.000000E-1	2.540000E00
5.520000E0	1.850000E0	5.550000E0	6.070000E0	3.530000E0
3.100000E-1	1.600000E-1	3.000000E-2	7.000000E-2	2.200000E-1
1.100000E-1	1.960000E00	4.750000E00	3.270000E00	3.760000E00
1.190000E00	4.500000E00	2.990000E00	1.100000E-1	8.100000E-1
4.100000E-1	2.100000E-1	1.000000E-1	1.960000E00	7.200000E-1
2.430000E0	1.730000E0	2.760000E0	4.680000E0	1.580000E0
1.100000E-1	1.800000E-1	3.800000E-1	4.500000E-1	8.000000E-2
1.480000E00	4.700000E-1	4.100000E-1	2.000000E-1	2.820000E00
1.060000E00	1.660000E00	7.000000E-2	1.300000E-1	1.400000E-1
1.330000E00	8.200000E-1	1.100000E-1	7.800000E-1	1.660000E00

LIST OF REFERENCES

1. Anderson, O.D., Time Series Analysis and Forecasting; The Box-Jenkins Approach, Butterworths, Boston, 1976.

2. Anderson, T.W., The Statistical Analysis of Time Series, John Wiley & Sons, New York, 1970.

3. Ansley, C.F., Spivey, W.A., and Wroblesk, W.J., A Class of Transformations for Box-Jenkins Seasonal Models, Applied Statistics, 16, No. 2, p. 173, 1977.

4. Box, G.E.P. and Jenkins, G.M., Time Series Analysis, Forecasting and Control, Holden-Day, San Francisco, 1970.

5. Chatfield, C. and Prothero, D.L., Box-Jenkins Seasonal Forecasting; Problems in a Case-study, Journal of the Royal Statistical Society, A, 136, Part 3, p. 295, 1973.

6. Control-Program 67/Cambridge Monitor System (CP-67/CMS) User's Guide, IBM Corporation, White Plains, New York, 1972.

7. Cox, D.R. and Lewis, P.A.W., The Statistical Analysis of Series of Events, John Wiley & Sons, New York, 1966.

8. Draper, N.R. and Smith, H., Applied Regression Analysis, John Wiley & Sons, New York, 1966.

9. The IMSL Library, Volume 1, International Mathematical and Statistical Libraries, Houston, Texas, 1975.

10. Jenkins, G.M. and Watts, D.G., Spectral Analysis and its Applications, Holden-Day, San Francisco, 1968.

11. Lee, W.L., An Application of CP/CMS to Time Series Analysis, Master's Thesis, Naval Postgraduate School, Monterey, 1977.

12. Mabert, V.A., An Introduction to Short Term Forecasting Using the Box-Jenkins Methodology, American Institute of Industrial Engineers, Inc., Norcross, Georgia, 1975.

13. Marquardt, D.W., An Algorithm for Least-Squares Estimation of Nonlinear Parameters, Journal of the Society for Industrial Applied Mathematics, Volume 11, No. 2, June, 1963.

14. Nelson, C.R., Applied Time Series Analysis for Managerial Forecasting, Holden-Day, San Francisco, 1973.

15. Pindyck, R.S. and Rubinfeld, D.L., Econometric Models and Economic Forecasts, McGraw-Hill, New York, 1976.

16. Wheelwright, S.C. and Mauridakis, S., Forecasting Methods for Management, John Wiley & Sons, New York, 1977.

17. Wheelwright, S.C. and Mauridakis, S., Interactive Forecasting, Univariate and Multivariate Methods, Holden-Day, San Francisco, 1978.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 55 Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
4.	Department Chairman, Code 53 Department of Mathematics Naval Postgraduate School Monterey, California 93940	1
5.	Associate Professor F.R. Richards, Code 55Rh Department of Operations Research Naval Postgraduate School Monterey, California 93940	3
6.	Distinguished Professor F.D. Faulkner, Code 53Fa Department of Mathematics Naval Postgraduate School Monterey, California 93940	10
7.	Professor R.N. Forrest, Code 55Fo Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
8.	Professor P.A.W. Lewis, Code 55Lw Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
9.	Associate Professor J.H. Hartman, Code 55Hh Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
10.	LT P.C. Olsen, USCG 16207 Pointer Ridge Drive Bowie, Maryland 20716	1

11. Mr. William E. Cralley 1
Center for Naval Analyses
1401 Wilson Boulevard
Arlington, Virginia 22209

12. Mr. Michael W. Davis 1
Patuxent River, Maryland 20670
655 Branch, SETD

13. LCDR S.R. Woodall, USN 2
711 South, Skyline Plaza
3705 South George Mason Drive
Falls Church, Virginia 22041

14. Professor G. Morris, Code 53Mj 1
Department of Mathematics
Naval Postgraduate School
Monterey, California 93940

15. LT James J. Carlin 1
Commanding Officer
Pacific Missile Range Facility
Hawaiian Area, Barking Sands
Kekaha, Hawaii

16. Mr. Martin Mandelberg 1
Naval Postgraduate School
SMC 1301
Monterey, California 93940

17. Major Paul M. Darling, USMC 1
1 Shubrick Road
Monterey, California 93940

Thesis
W833
c.1
Woodall
178468
An interactive software package for time series analysis.